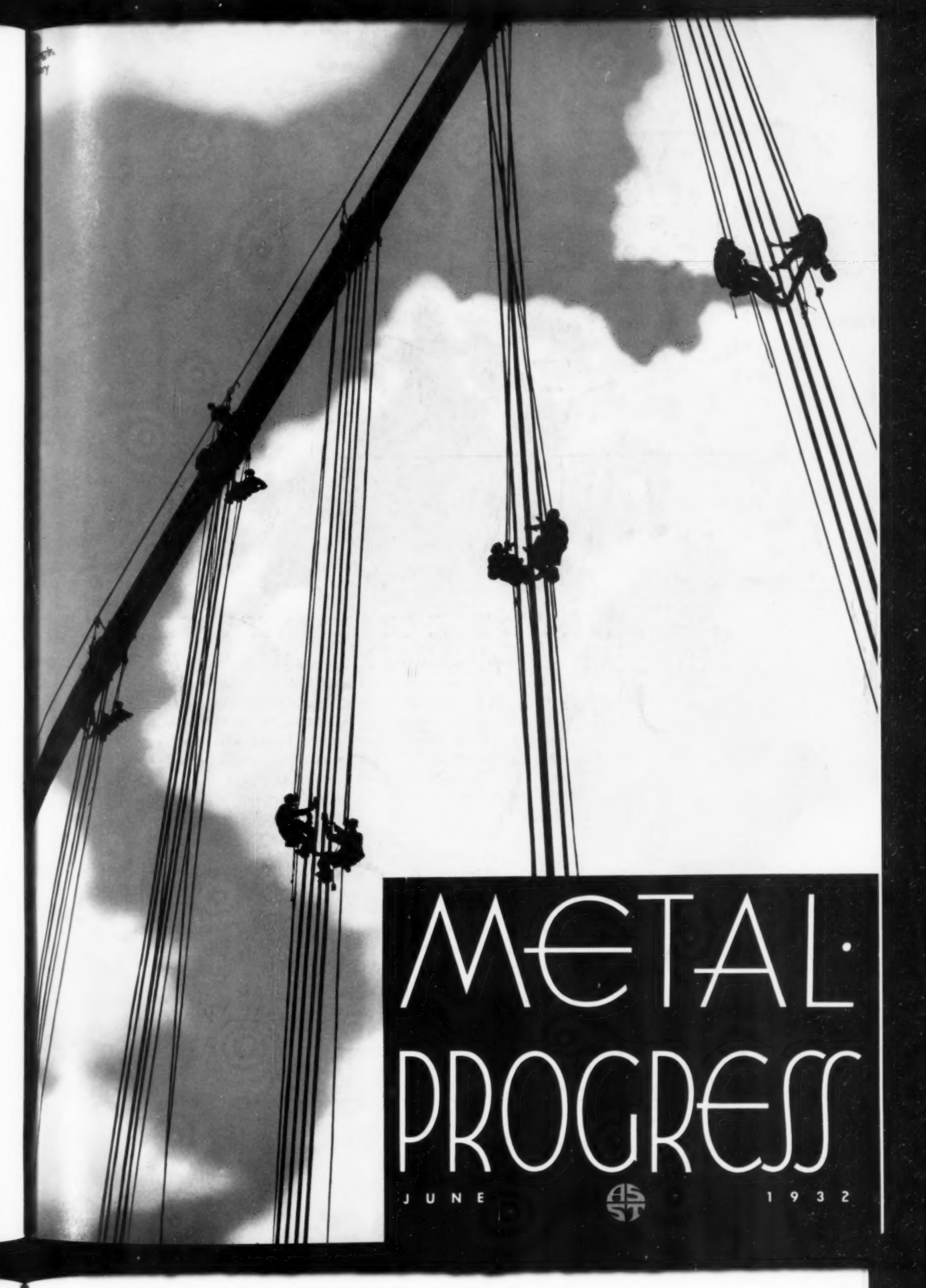
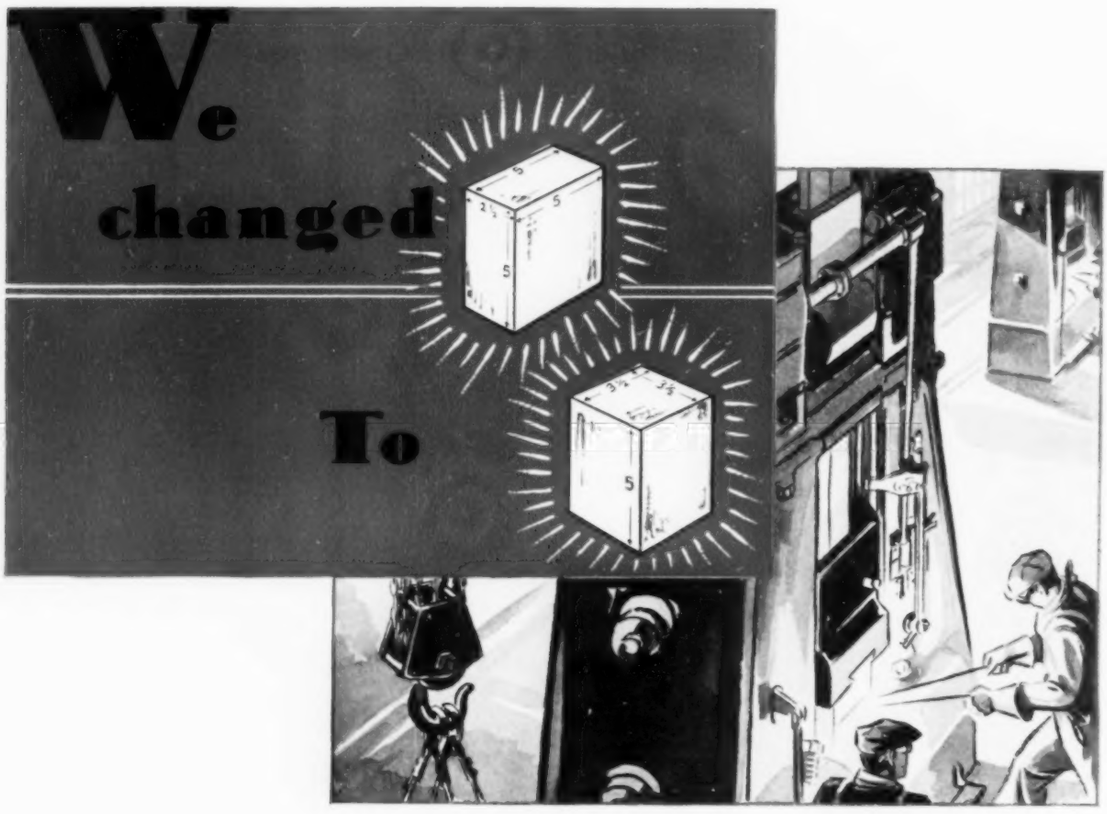


METAL PROGRESS

JUNE 1932



AND THE SEAMS DISAPPEARED

A PROMINENT drop-forging shop . . . producing steering knuckles for a well-known automobile company . . . and an epidemic of seam-like defects that showed up at the spindle end. Naturally, the drop forger laid the trouble to the steel.

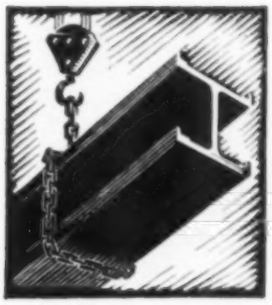
Again Republic Metallurgists responded to the call. Carefully selected forging blanks, conceded to be free from defects, were forged under various hammers, in a variety of ways. Soon they discovered something — the defects occurred even when the stock was stood on end (length of the blanks being the same as the width). More checking, more study and they were sure of their ground — the proportions of the forging blank were wrong — the ratio of height to width was too great. Unless the blank was placed just so under the hammer, laps resulted.

On the recommendation of Republic Metallurgists, dimensions of the forging blank were changed from 2½" x 5" x 5" to 3½" square x 5". This did not increase the weight of the forging blanks, or add to the cost — but it did eliminate the trouble.

Resourceful, ingenious fellows, these Republic Metallurgists. At home in a pair of overalls — running a drop-forging hammer, operating a furnace, checking a carbonizing mixture, planning a heat-treating cycle, redesigning a forged part for better contours — doing everything but selling — they never carry a price list.

CENTRAL ALLOY DIVISION
REPUBLIC STEEL CORPORATION
Massillon, Ohio

AGATHON ALLOY STEELS



METAL PROGRESS

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JUNE, 1932 VOL. 21, No. 6

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Ernest E. Thum, Editor

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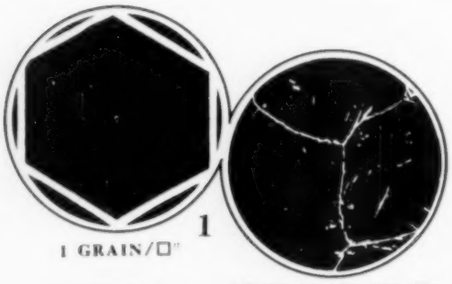
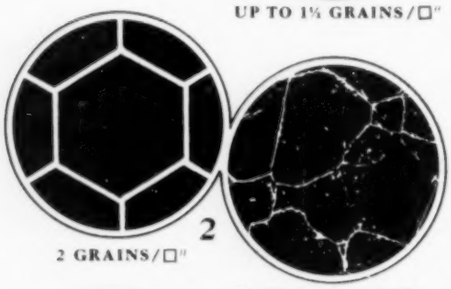
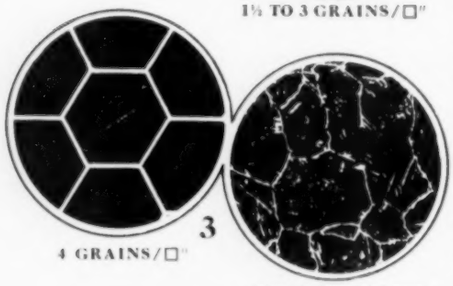
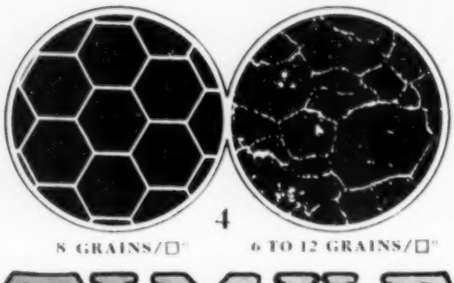
GRAIN SIZE CONTROL

An Important Attribute of TIMKEN STEELS









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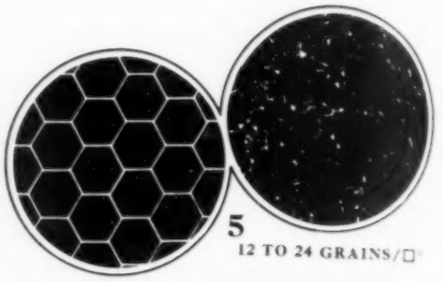

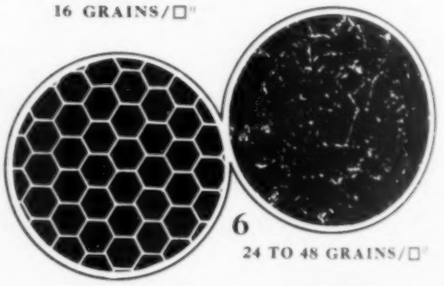

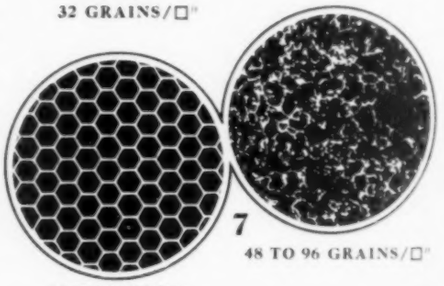

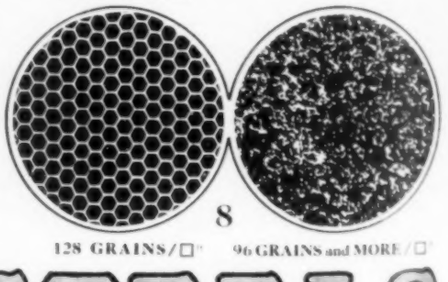

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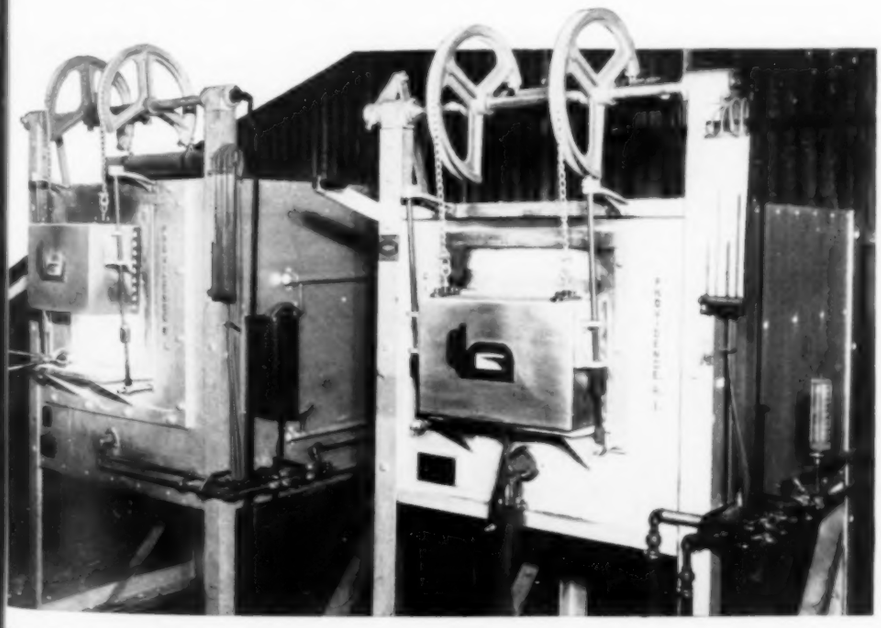

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M. J. Udy | T. D. Yensen | H. E. Rogers | R. H. Harrington | J. R. Townsend | A. M. Steever

AUTHORS IN THIS ISSUE

The professional career of MARVIN J. UDY, whose article on chromium plating is on page 23, began at Midvale, Utah, where he was assistant research chemist for U. S. Smelting Co. He has specialized in non-ferrous metallurgy ever since, during his succeeding connections with Hooker Electrochemical Co., with Haynes Stellite Co., as chief chemist and later as manager of the company's cobalt mine and with Union Carbide and Carbon Research Laboratories. His plating experience has been extensive. At present he is with Swann Research Corp., an affiliation of Swann Chemical Co.

Hipernik is described on page 28 by T. D. YENSEN who has charge of the magnetic section of the Westinghouse laboratories. Mr. Yensen is a graduate of the University of Illinois. In 1927 he received the degree of Ph. D. from California Institute of Technology. He was the first man to develop magnetic materials with a permeability higher than 15,000 and has since prepared some with permeability between 50,000 and 100,000. Hipernik was discovered and developed by him.

Heat treating of teletype parts is told on page 35 by the metallurgist of the Teletype Corp., HARRY E. ROGERS. Mr. Rogers attended Winona Technical Institute, Indianapolis, and before joining Teletype four years ago, was engaged in chemical and metallurgical work with several plants.

Magnetic hardening is again discussed, this time by RICHARD H. HARRINGTON of General Electric research laboratories. This discussion will be found on page 40. Mr. Harrington has received the degree of B.S., M.S. and Doctor of Science in Engineering from the University of Michigan in 1925, 1926 and 1929 respectively.

J. R. TOWNSEND's description of a laboratory for welding study may be found on page 42. Mr. Townsend has been a member of the staff of Bell Telephone Laboratories since 1925. He has received the Dudley Medal of the A. S. T. M. for joint authorship of an article on physical testing of nonferrous sheet metal.

ADAM M. STEEVER is familiar to readers as chief metallurgist for Great Lakes Forge Co. and as author of three articles on forging previously published in this magazine. His professional career includes connections with Buick and Chevrolet and five years with Ingalls Shepard Division of Wyman Gordon Co. He was chairman of Chicago Chapter, A.S.S.T. in 1928. His article begins on page 50.

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Copper Plating Tank

CHEMICAL AND PHYSICAL ACTIONS IN CHROMIUM PLATING BATH

By Marvin J. Udy
Chemical Engineer
Anniston, Ala.

WHILE chromium plating is not a new discovery, the commercial application has been developed within the past six or seven years, largely as an application of the modern sciences of physical chemistry and electrochemistry. It requires much closer control than most common plating operations, and the average workman cannot readily appreciate the fundamentals of the process. Some failures have therefore been almost inevitable.

To avoid such disappointments it is well for metallurgists and engineers in control of manufacturing processes to understand the chemistry and technique. In what follows an effort will be made to clarify these points, chiefly by noting the differences from the ordinary processes for nickel, copper, cadmium, and zinc.

Ordinarily, nickel plating baths are composed principally of nickel sulphate dissolved in water. They may be made up in various strengths and used hot or cold. Small amounts of boric acid and nickel chloride are added to promote certain characteristics essential to smooth operation and good deposits. A typical and common nickel plating bath contains 32 oz. per gal. of nickel sulphate, 2 oz. per gal. of nickel chloride, and the same amount of boric acid.

Bright Auto Parts

If we place two metallic electrodes in such a bath and apply a definite voltage from a direct current circuit or generator, we find that this bath conducts the current very readily. If we examine the electrodes after the current has passed for some time, we find that metallic nickel has been deposited on one of the electrodes (the cathode), while the other (the anode) has been corroded and dissolved away. The direction of the flow of the current is from positive anode to negative cathode. In nickel plating the anode is of pure nickel and as it is dissolved away it supplies the bath with nickel to replace that which has been deposited at the cathode, which in practice is the article on which we wish to obtain a deposit of nickel.

In commercial work there is a very even balance between the nickel deposited at the cathode and that dissolved at the anode, or, in other words, the "cathode current efficiency" and "anode current efficiency" are very nearly equal, and it is an easy matter to maintain a constant bath composition, which is essential for consistent results.

The nickel plating bath may be used hot or cold. Current densities range from 2 amp. per sq.ft. to 40 amp. per sq.ft. of cathode area. As a general rule high current densities are used with high temperatures and vice versa. The temperature is ordinarily between room temperature and 110° F.

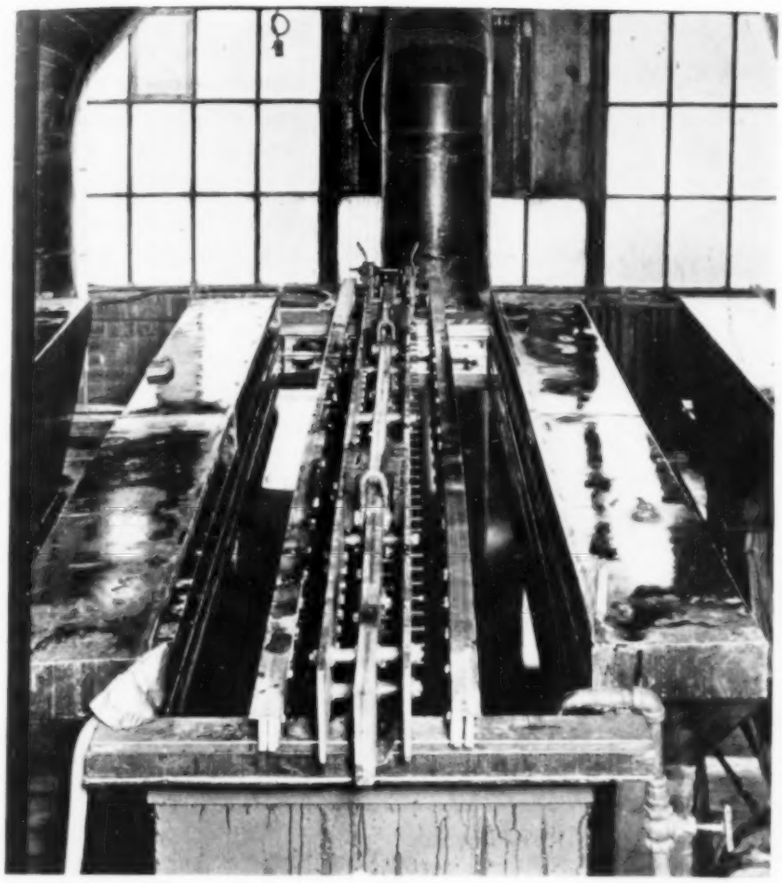
Chromic Sulphate a Non-Conductor

Turn now to chromium plating. We have salts of chromium analogous to nickel sulphate, and it might be possible, therefore, to use a bath of chromic sulphate as we do nickel sulphate and obtain chromium deposits. We find, however, that the sulphates of chromium are many, and unstable and variable in their character.

If we attempt to electrolyze a chromic sulphate bath as we do a nickel sulphate bath, we find that it resists the passage of the current unless we add free acid or some highly conductive salt, or apply an extremely high voltage. When some current passes through the bath some metal is deposited at the cathode but it is usually of a very poor appearance. At the anode we find that instead of a direct solution of the chromium as chromic sulphate to replenish the bath, we actually are producing chromic acid, or are oxidizing the chromic sulphate to chromic acid. (As a matter of fact, one method of making chromic acid is to electrolyze a solution of chromic sulphate, using an anode of lead.) These auxiliary reactions destroy the balance of constituents in the plating bath, without which suitable deposits cannot be produced.

While deposits *can* be produced from this

Chromium Plating Tanks Require Strong Draft to Sweep Acid Mist From Surface of Bath Lest Workmen and Equipment Should Suffer



For Precision Plating the Work and Anodes Are Rigidly Fixed in Correct Relationship and Bolted to Composite Bus Bar

type of bath, it has not been possible to stabilize it and make it commercial.

Chromic acid is the end product of any electrolysis of chromic sulphate. Unlike chromic sulphate, chromic acid is highly conductive. However, electrolysis of pure chromic acid solution does not result in the deposition of chromium; the action is similar to the electrolysis of a sulphuric acid solution, since only oxygen and hydrogen gases are produced. A small amount of one of numerous other acids or acid radicals in the form of a soluble salt must be added before any metal is deposited at the cathodes. Addition of another acid reduces a certain proportion of chromium salts in the solution, and from these reduced salts metallic chromium can be deposited.

Production of Chromium Ions

The above facts stated in the language of the electrochemist are as follows: A solution of pure chromic acid contains only hydrogen ions and chromate ions. In order to deposit chromium some free chromium ions must be present. Free chromium ions in solution are formed by the addition of an acid radical, such as sulphuric acid or a soluble sulphate. In the formation of the free chromium ions a part of the chromic acid is reduced from the hexavalent state to the trivalent state and is held in solution by the excess of chromic acid. The chromic acid apparently acts as a carrier for the free chromium ions and for the electric current.

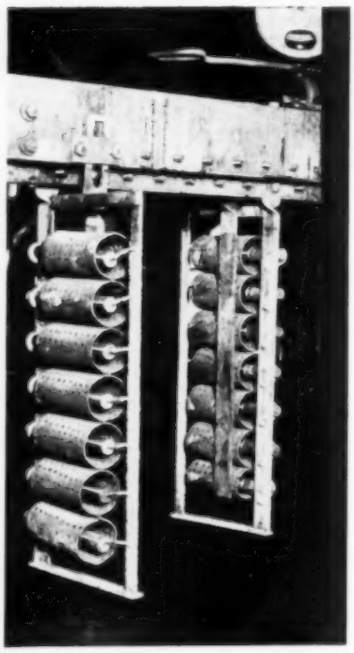
This is quite a different situation from that existing in nickel plating where no such carrier or catalyst is needed; the nickel sulphate in solution forms free nickel ions and free sulphate ions which readily conduct the current. Fortunately, the chemistry of chromium plating, while complex, is not so complicated in its application as to make it unsuitable for commercial use.

For the reasons summarized above, the chromium plating bath as it is used today is made up of chromic acid and a small amount of another acid, or the corresponding salt, preferably sulphate. A typical bath contains 32 oz. per gal. of chromic acid (H_2CrO_4) and 0.40 oz. per gal. of sulphuric acid (H_2SO_4).

This particular bath is especially good for producing heavy deposits for wear resistance. For most work a temperature of 110° F. and a current density of 200 to 300 amp. per sq.ft. are most favorable, although the temperature may vary from 75° F. to 140° F. and the current density from 100 to 1000 amp. per sq.ft. or more, depending on the type of work and results desired. It will be noted that these current densities are very much higher than those used in nickel plating.

The cathode current efficiency in this particular bath will vary from 10% to 35% (com-

pared with 95% for a nickel bath). The anode current efficiency, where soluble chromium metal anodes are used, will be 85% to 95%. This great difference in anode and cathode efficiency makes it necessary to combine insoluble lead anodes with the chromium metal anodes in the ratio of approximately 5.5 lead to 1 chromium, so as to dissolve only as much chromium as is deposited on the work. As has been noted before, chromium metal anodes go into solution as chromic acid; a more practical and cheaper plan is therefore to make all anodes of lead and supply the bath with chromium by the direct addition of chromic acid.



After a short period of use a bath originally of the above composition will contain definite constituents in more or less stabilized ratio. These constituents are chromic acid, trivalent chromium, and a sulphate radical. There should always be from 75 to 100 times as much chromic acid present as sulphate radical. The trivalent chromium is partly due to the sulphate present and must be kept below certain definite limits for consistent results.

Simple Tests for Control

In order to control the bath and its plating characteristics, it is necessary to control the chromic acid concentration and the sulphate radical concentration as well as the temperature. Using lead anodes, the chromic acid is replenished by adding chromic acid of the proper purity to maintain a definite gravity reading. The control of sulphate radical is very important and has to be done by analyzing the bath frequently. Precise analysis requires considerable time, but figures of sufficient accuracy can be had in about an hour. There have also been developed rapid empirical tests to indicate the sulphate present (such as the bent cathode test, cavity test, and the meniscus test), any one of which can be used very conveniently in plant operation.

Much of the necessary plating equipment is similar to that used for nickel or copper. One important addition is necessary: The deposition of chromium is accompanied by a strong evolution of hydrogen gas, which carries an acid mist into the air, detrimental to workmen and surroundings. Strong suction into ventilators along the tank tops is required. Chromium plating has other peculiarities arising from the poor "throwing power" of the solution, the necessity for high current densities, the low cathode current efficiency, and the strong etching effect which the solution has on some of the more common non-ferrous alloys.

Throwing power is that property of a plating solution which determines the distribution of metal upon a cathode of irregular shape. In electroplating articles with recesses it is especially desirable to use a plating bath with good throwing power in order to coat the depressions without putting an excessive amount of metal upon the raised portions.

A quantitative measure for throwing power proposed by Blum and Haring is "the deviation (in per cent) of metal distribution ratio from the primary current distribution ratio." It depends upon cathode polarization, solution conductivity, and cathode efficiency.

When plating articles of irregular shape we find that the current density on those parts of the cathode nearest the anode is greater than on those areas farthest away. If the farthest part of the cathode is five times as far from the anode as the nearest part, then the "primary current distribution" will be 5 to 1. If current efficiency is the same for all the current densities and this primary current distribution prevails, the "metal distribution" on these points will also be in the ratio 5 to 1. However, due to polarization, conductivity of the bath, and changes of cathode efficiency with cathode current density, metal distribution is not in the same ratio as the primary current distribution. In baths of good throwing power we find there

is a relatively smaller amount of metal deposited on the nearer portions of the cathode, while in baths of poor throwing power the reverse is the case.

If we find that our deposited metal is distributed in the ratio of 4 to 1 when the primary current distribution ratio is 5 to 1, we have by definition a throwing power of

$$(5\text{–}4) \div 5 = +1 \div 5 = +20\%$$

If, on the other hand, the metal distribution is 6 to 1 we have a throwing power of

$$(5\text{–}6) \div 5 = -1 \div 5 = -20\%$$

In nickel, copper, and cadmium plating relatively good throwing powers are readily obtainable, so that inequalities in the current distribution are somewhat equalized by varying efficiencies over the article to be plated. Positive throwing powers of 15% to 35% are possible, particularly with the cyanide solutions of copper and cadmium.

In chromium plating the current efficiency is low and depends almost directly on the current density for any given set of conditions. If current density is increased beyond certain limits in an effort to increase the efficiency, current distribution difficulties are only intensified, and therefore any increased throwing power gained by increased efficiency is overshadowed by poorer current distribution. Could the efficiency of the chromium plating bath be increased without increasing the current density, better results might be expected. No means of doing this has yet been discovered. Addition agents and chemicals, so far proposed, unbalance the bath and reduce its efficiency. Lowering the temperature (all other conditions remaining constant) will increase the current efficiency, but even then the throwing power values computed as above are negative.

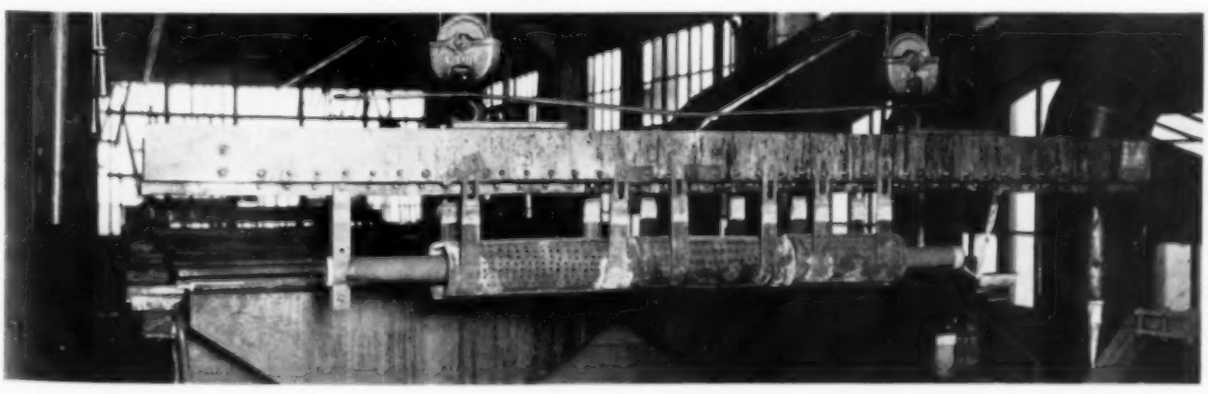
The high current densities required are responsible for poor current distribution and the problem of gas. The low efficiencies obtained in chromium plating mean that large volumes of hydrogen and oxygen are liberated at the cathode and anode, respectively. These gases affect the resistance in the various parts of the bath, and should therefore be properly distributed. For precision plating it is absolutely necessary that good current distribution be obtained, even though the current densities are high and much gas is evolved.

Conforming Anodes Desirable

The use of insoluble anodes presents a mechanical difficulty, but it is doubtful whether they are not really an asset to the process, particularly for precision plating of heavy deposits. By using proper equipment, anodes can be conveniently shaped to conform to the shape of the piece in such a manner that the current can be led equally to all parts to be plated and heavy deposits built up with considerable accuracy. Conforming anodes are not advocated for all types of plating; it will depend upon the particular piece to be plated and the result desired.

Conforming anodes permit better current distribution at high current densities because the tank can then be operated at lower voltage. When properly designed they will be at the proper distance from all parts of the cathode in order to give the proper voltage and current density, and thus deposit uniformly.

Views on These Two Pages Show How Conforming Anodes, Made of Perforated Lead Sheet, Are Joined Together and to Bus Bar, Surrounding Objects to be Plated—a Heavy Shaft and a Number of Plug Gages



HIPERNIK & OTHER MAGNETIC ALLOYS

GREAT IMPROVEMENTS

DUE TO HEAT TREATMENTS

By T. D. Yensen
Manager, Magnetic Division
Westinghouse Research Laboratories
East Pittsburgh, Pa.

JUSTIFICATION for presenting this subject before the American Society for Steel Treating is contained in the title. "Hipernik" is a direct result of an attempt, by means of a heat treating process pure and simple, to improve upon the magnetic properties of an alloy that had been known for years and that had already been used to a limited extent commercially. While the characteristics of the alloy are of importance chiefly to electrical and communication engineers, metallurgists will be interested in hearing something about the developments that led to this specialized product and that resulted in magnetic properties which surpassed our fondest expectations.

It began in the early 1920's when radio broadcasting became an actuality. Efforts soon were directed toward improving the quality of the reception. One important element in a radio receiving set is the audio frequency transformer, which serves the purpose of amplifying the incoming signals. Without entering into the intricate technical questions as to how and why a transformer with a magnetic core amplifies the signals more than one without a magnetic core, our intuition and common sense tell us that the better the magnetic properties of the core material, the greater the amplification will be. This is particularly true for currents of low frequencies. For this reason the best grade of silicon iron was used for these early transformer cores.

Thin Strips Magnetized By Earth's Field

However, we are never satisfied if there is a chance for something better, and so the radio

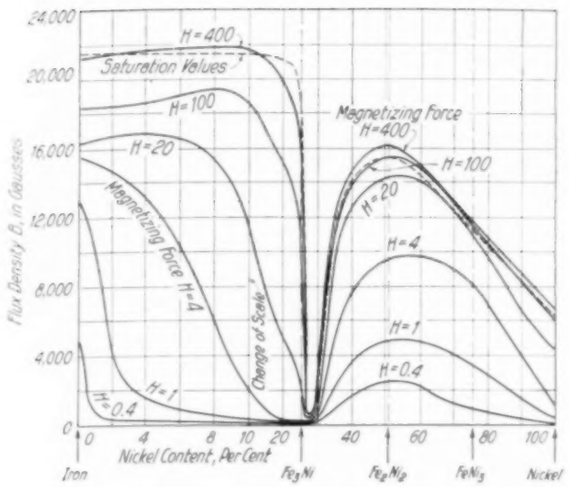


Fig. 1—One of a Series of Diagrams Published in 1920 Covering Magnetic Properties of Alloys of Electrolytic Iron and Nickel, Melted and Annealed in Vacuum. Curves show flux density B in the various alloys (measured in gausses) induced by various magnetizing forces H, varying from 0.4 to 400 gilberts per centimeter. Note that the 50% Fe-Ni alloy is strongly magnetized in very weak fields

engineers turned to our research department for a better magnetic material. Based on data from a complete investigation of iron-nickel alloys published in 1920 by the writer in *Transactions*, American Institute of Electrical Engineers, the 50% Fe-Ni alloy was recommended (see Fig. 1). As shown in Fig. 2, this had an initial permeability between 2000 and 3000, compared with less than 2000 for 36% nickel-iron and 400 for 4% silicon-iron. Samples were rolled into 14-mil (0.33 mm.) strips, made into audio transformer punchings and annealed in vacuum at 900° C. (1650° F.). Tests confirmed the superiority of the 50% alloy for this application, and production started on a small scale, using laboratory facilities with satisfactory results.

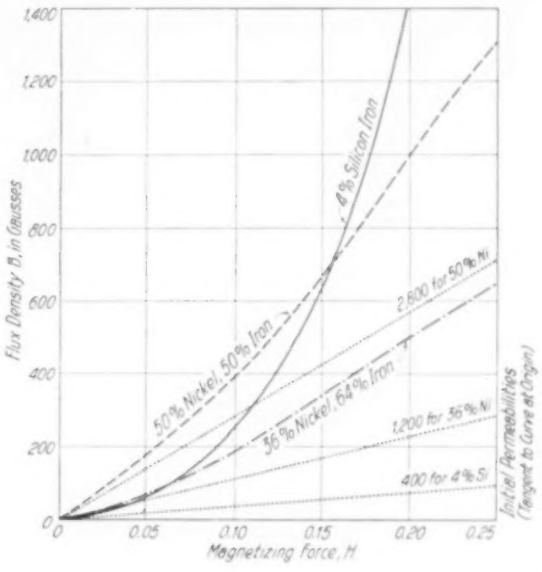
Reception was greatly improved, particularly for the low frequencies, and based on these results the alloy was gradually adopted as standard by the manufacturers of radio equipment for use in high quality receiving sets, and production had to be advanced to a larger scale. High frequency induction furnaces were constructed of 200 lb. capacity, and larger annealing furnaces were used.

At this point, however, trouble started (in the fall of 1923) — as is not uncommon under similar circumstances when the scale of production is changed. Some of the audio transformers proved unsatisfactory, and magnetic tests showed the punchings to be much below par. Reannealing them at the laboratory in vacuum or nitrogen at various temperatures produced no appreciable improvement.

Having had but slight experience in diagnosing troubles with iron-nickel alloys, we did not know exactly what to look for, but with one good sample and one poor sample, we could at least look at them to see if we could detect any differences. Magnified 100 times, the polished cross-sections showed the poor sample to contain numerous inclusions, whereas the good one appeared fairly free from inclusions. In other words, we had what in steel parlance would be called dirty and clean metal. Further examination and considerations led to the opinion that the inclusions were chiefly oxides, and the subsequent developments were based on the hypothesis that the trouble was due to oxygen in solution and precipitated oxides.

Some preliminary tests were first made to determine the effect of rolling, with the result shown in the dashed lines at the left in Fig. 3.

Fig. 2—Magnetization Curves for Audio Transformer Alloys Available in 1923. Horizontal scale is magnified to show conditions in weak fields. Permeability is the measure of the ease with which the elementary magnetic particles in the alloy are oriented. The slope of a line drawn from the origin to the magnetization curve measures the permeability at that point. Initial permeability, or the tangent at the origin, is much higher for the 50% nickel alloy, and this alloy readily responds to very small changes in magnetizing forces



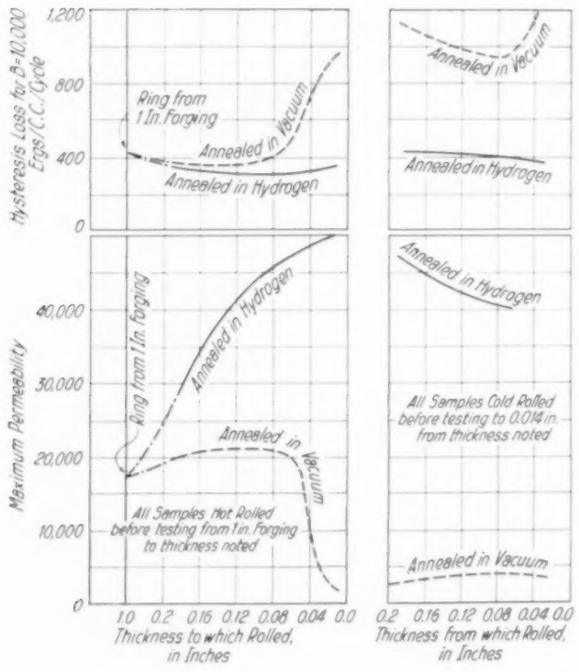


Fig. 3—50% Alloys, Made and Annealed in Vacuum, Have Poor Magnetic Properties (Low Permeability and High Hysteresis) When Hot or Cold Rolled to Thin Sheet. Thin sheets, annealed 8 hr. at 1000° C. or 1830° F. in hydrogen, have fine magnetic properties

The ingot from which the samples were prepared was made from electrolytically refined metals in a vacuum, using a high frequency induction furnace. All samples were vacuum annealed at 1000° C. (1830° F.) for 8 hr. before testing. Starting out with fairly good magnetic properties of the forged bars machined into rings, no marked change occurred in the magnetic properties (as measured by maximum permeability and hysteresis loss at flux density of 10,000 gausses) due to the process of hot rolling down to 0.060 in. (1.5 mm.). In hot rolling from 0.060 to 0.014 in., however, the magnetic properties were drastically changed, the maximum permeability dropping from 20,000 to 2000 and the hysteresis loss increasing from 400 to 850 ergs per c.c. per cycle.

At first thought this change suggested oxidation during the hot rolling process, but other evidence led to a different conclusion. In the first place, the original samples used in the preliminary investigation had also been hot rolled to 0.014 in. and these had much better properties than the ones shown in Fig. 3. Furthermore, if the poor properties were due to oxidation during the *hot* rolling process, then *cold* rolling should result in better properties. Cold rolling to 0.014 in. from various thicknesses was consequently tried and very nice-looking sheets were produced. The magnetic results, however, were as bad as, if not worse than, those for the hot rolled samples, as shown in the dashed lines at the right in Fig. 3. A satisfactory explanation to account for these results was not immediately found.

Rings Annealed in Hydrogen

Acting on the assumption that the poor magnetic properties in some way or other are due to oxygen in solution or to precipitated oxides or perhaps partly to both, it should be possible to remedy the trouble by hydrogen annealing. The oxides in question could only be oxides of iron, nickel, and manganese, for these alloys were made under laboratory control and of purest metals. These oxides would be in equilibrium with the oxygen in solution and by removing the oxygen first on or near the surface by means of hot hydrogen, other oxygen atoms would be constantly diffusing from the interior, and there would be a gradual reduction of the oxides. In time it should therefore be possible to produce a nearly oxygen-free alloy in this way.

The above hot rolled and cold rolled samples were consequently annealed in a stream of hydrogen at 1000° C. for 8 hr. The solid lines in Fig. 3 show the change which occurred. The results were most gratifying. Not only were the magnetic properties of the thin samples greatly improved over the corresponding vacuum annealed samples, but they were much better even than those of the forged rings after vacuum annealing. The first public announcement of these results was made by the writer on Sept. 19, 1924, at the 100th birthday celebration of the Franklin Institute in Philadelphia (and published in its *Journal* in 1925). United States patents 1,807,021 and 022 were granted May 26, 1931.

It was at first surprising to find that hydrogen annealing did not improve the ring from the forging and only improved slightly the samples 0.185 in. thick, but in the light of the above assumption that the improvement is due to a diffusion phenomenon, this is what might be

IMPROVEMENT IN 50% NICKEL-IRON ALLOY

	Maximum Permeability	Hysteresis Loss for B=10,000
50% Nickel Alloy, before 1924	5,000	1,000 Ergs
1924 Hipernik	40,000 or more	400 or less
1932 Hipernik	80,000 or more	200 or less
Exceptional lots	150,000 or more	100 or less
4% Silicon Iron (Commercial)	12,000 or less	800 or more

expected. The thicker the sample, the longer it should take to remove the oxygen.

Fig. 4 shows the difference between the magnetization or B-H curves for good commercial silicon iron and for the 50% nickel-iron alloys before and after 1924 as described above. The improved alloy is the one to which the name "Hipernik" has been given. It had higher initial permeability (3000 to 6000), at least eight times the maximum permeability (40,000 to 80,000), and less than four-tenths of the hysteresis loss (300 to 400 ergs) of the 50% alloy as first used.

It is very difficult to assign definite causes for the improvement in terms of differences in chemical composition, as in the case of unalloyed iron. It is only by the most refined methods of chemical analysis that quantitative relationships have been obtained that point to oxygen as the chief determining factor in the problem.

It was soon found that the above improvement could be obtained occasionally by starting from a metal made in commercial furnaces, especially if a higher annealing temperature was used (up to 1200° C. or 2200° F.). Further study showed what the necessary and sufficient conditions are for obtaining good results consistently, and at the present time, the passing limits for Hipernik are those shown in the above table for 1924 Hipernik.

Our engineers are not satisfied, however, unless the tests show a maximum permeability of at least 80,000 and a hysteresis loss of less than 200. Results become exceptional only when they show values that are better even than these. It should be noted that all these results have been obtained with material produced in commercial furnaces in ton lots and annealed by routine commercial processes. The only work done in the laboratory has been the check testing.

Now, to go back to the question of the very poor magnetic properties of the sheet material as shown in Fig. 3. What can be the real cause?

We saw that the result was practically the same whether the material was rolled hot or cold, so that oxidation during the rolling process could not be the cause. The fact that the samples prepared in the Arsem vacuum furnace, where a reducing atmosphere of carbon monoxide is present, gave better results than samples prepared in the high frequency vacuum furnace, where the atmosphere was neutral or slightly oxidizing, adds weight to the conclusion that the cause is to be sought in the base material itself.

On this basis, the following explanation is offered: Presence of oxides in the ingot, observable at room temperature, means that the metal is saturated with oxygen in solution at the melting point. In addition to the observable inclusions, there is present in the metal the difference between the oxygen solubility at the

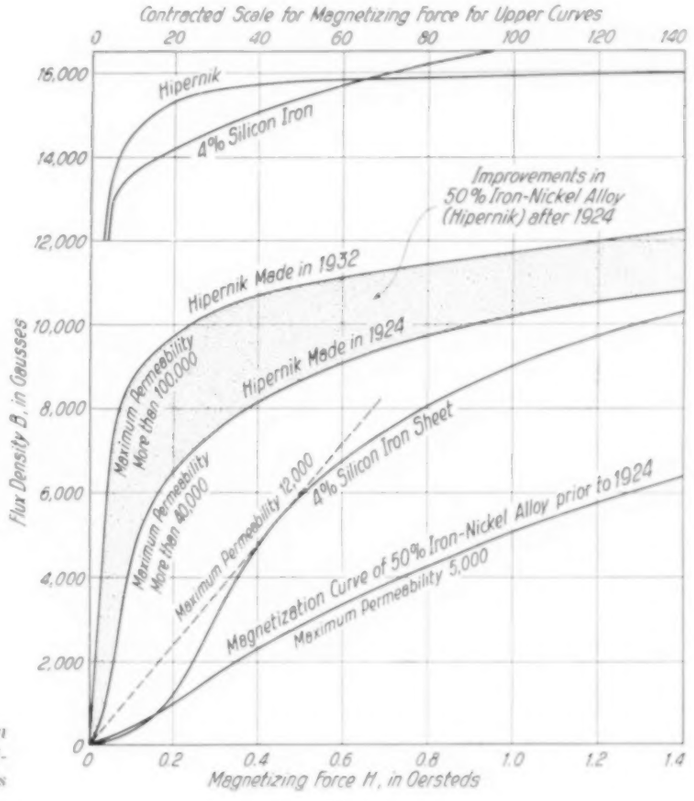


Fig. 4—Comparative Magnetization Curves for Hipernik and High Silicon Iron in Weak and Strong Fields

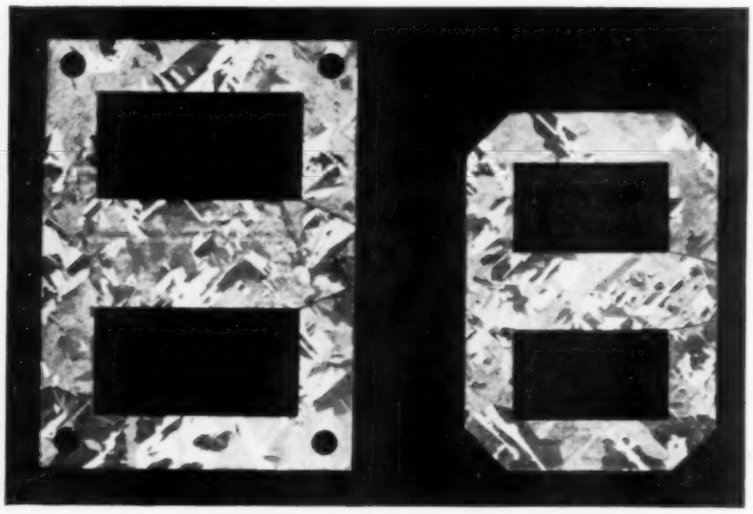


Fig. 5—Etched Hipernik Audio Transformer Punchings Show Large Twinned Grains. At right, Fig. 6—Unannealed 0.014-in. sheet shows fibrous cross-section. Annealing in hydrogen improves magnetic properties at least 100 times

volume today is used for current transformers in connection with instruments and circuit breakers. The high permeability and the low energy loss as shown in the table on page 31 have a very beneficial effect on the accuracy and reliability of the apparatus. Other possible applications are apparent to electrical engineers, but it may be said that, in general, wherever a low-loss, high-permeability core material is desired (as in transformers) or one having low residual magnetism (which essentially means a low coercive force, as required for relays) there is no better material available today than Hipernik, taking all factors into consideration.

melting point and at room temperature. This oxygen exists in the form of colloidal particles of oxide, invisible under the microscope and dispersed in the crystal grains. This is essentially the structure that gives the low magnetization curve of Fig. 4. When such a structure is rolled into thin sheets, the large oxide inclusions are broken up into minute particles that become scattered and embedded in the grains and thus become more effective in distorting the lattice structure than before (when it was concentrated in large particles in a few spots). The result is a greatly increased hysteresis loss and lowered permeability. Cold rolling should be even worse than hot rolling, as the curves show to be true, although the difference is not great. Hydrogen annealing at high temperatures, as already mentioned, is an effective remedy in either case.

Having developed this supermagnetic alloy and demonstrated its scientific value, the question is naturally asked: What is its economic usefulness? Its use as core material for audio transformers was its first application and it is still widely used as such. But a much larger

Interesting Internal Structure

So far we have dealt more or less with abstract values. Our minds always crave something tangible, at least something to look at that can help us to form a picture of the things we talk about. First, examine Fig. 5, a photograph of some etched Hipernik punchings, showing the macrostructure. Large grains are in evidence with plenty of twinning. Going a bit deeper into the structural features, and looking at the metal under a magnification of 100

diameters, we show the unannealed and the annealed samples side by side in Fig. 6. It should be noted that the magnetic properties of the two are in the ratio of 1 to 100.

Atomic Arrangement

In the third exhibit we are going still deeper and are trying to represent the atomic arrangement of some of the iron-nickel alloys. Looking first at Fig. 1 (page 29) which represents the magnetic properties of the entire alloy system, we see two regions that appear particularly interesting, the cusp just below 30% Ni and the maximum at 50% Ni. We know from X-ray analysis that the structure changes from the body-centered cubic lattice of iron to the face-centered cubic lattice of nickel between 25 and 30% Ni. It is interesting to note that 26% Ni corresponds to the formula Fe_3Ni and, if the alloy is homogeneous, may have the structure labeled Fe_3Ni in Fig. 7. Such an atomic arrangement may be supposed to be non-ferromagnetic. At 51% Ni, corresponding to Fe_2Ni_3, we also have a chance to get a homogeneous alloy if the atoms are arranged as shown in the space lattice labeled Fe_2Ni_3. This is the composition from which Hipernik is made. It is also of interest to note that a third chance for homogeneity exists at 76% Ni, corresponding to $FeNi_3$, very close to the composition originally used as a base for the very magnetic material called Permalloy. This, it will be seen, is just the reverse structure of the non-ferromagnetic alloy Fe_3Ni.

It seems logical to suppose that the homogeneity, as well as the purity, of these alloys has something to do with their remarkable magnetic properties.

Let us consider these five materials at greater length.

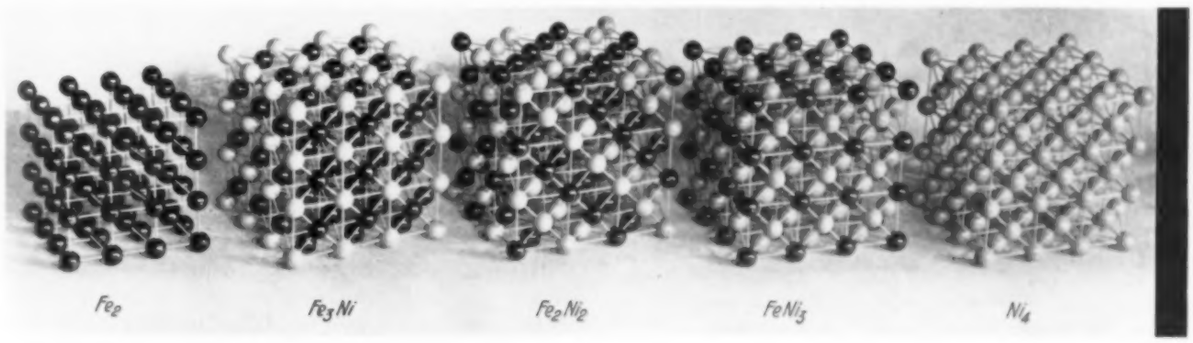
In iron (Fe_2), containing less than 0.1% total impurities, there can be little chance for inhomogeneities in structure, and variations in magnetic properties are mostly due to the impurities and the form in which they exist. This proposition was stated by the writer in a contribution to the *Transactions* of the American Institute of Electrical Engineers in 1924, and is now so universally accepted as to cause no great amount of argument. For nearly pure iron prepared with the greatest of care under laboratory conditions (99.99% Fe) and Armco iron (99.9% Fe), a commercial tonnage product, we get these differences in magnetic properties:

	Maximum Permeability	Hysteresis Loss B = 10,000
99.9 % Fe	6000	2500
99.99% Fe	60,000 or more	200 or less

This difference can be demonstrated by means of the simple magnetometer shown in Fig. 8. The purer iron becomes highly magnetized in the earth's magnetic field and becomes completely reversed by simply reversing the orientation of the rod. The other rod acts very differently. The earth's field has but little effect on it, and if it is highly magnetized (as by touching it to the compass needle) the earth's field will not reverse its magnetization. It then becomes a weak permanent magnet.

The non-ferromagnetism of the 26% Ni

Fig. 7—Models of Pure Iron-Nickel Crystal Structures. Hipernik corresponds to Fe_3Ni, midway between the very magnetic iron and the weakly magnetic nickel. Permalloy corresponds to $FeNi_3$ and in it the dark-colored balls representing iron atoms and the light-colored nickel are in reverse position to that in FeNi which is non-ferromagnetic as far as we now know



alloy (Fe_3Ni) may be a function of the homogeneity of the atomic arrangement, as the presence of even small regions containing less than 26% Ni with body-centered cubes or more than 26% Ni with face-centered cubes would produce a marked change in the magnetic properties of the alloy.

Homogeneity Important

We have seen what marked changes take place in the 50% range (Fe_2Ni_2) by removing impurities. Some of the variations, however, that are encountered are undoubtedly due to lack of homogeneity, as, for example, by the presence of regions corresponding to Fe_3Ni and others containing $FeNi_3$, one of which may be non-ferromagnetic while the other has much lower saturation values than Fe_2Ni_2. (In Fig. 1 the saturation values are shown dotted.) The difference in magnetic properties of the 50% Ni alloy of 1923 and the present-day Hipernik can also readily be demonstrated by means of the magnetometer or by means of two strips shown in the cut at the head of this article. Held in the earth's field, the Hipernik strips become magnetized to such an extent as to stick together, whereas no such attraction can be detected with the ordinary alloy.

Fig. 8—Magnetometer Gives a Simple Test for Permeability of Metal Rods. If a rod of purest iron, Hipernik or Permalloy is directed toward the earth's magnetic pole, as shown, and the base turned so the magnetic needle is at rest on the meridian, then the needle will just about reverse its direction when the rod is swung 180°, pivoting about the socket at the lower end. For demagnetized Armco iron, 99.9% pure, the needle of the device swings only about 5°

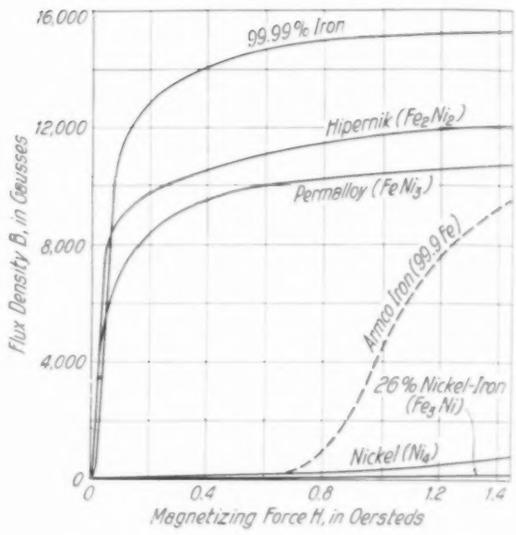


Fig. 9—Magnetization Curves at Low Field Strengths for the Principal Members of Iron-Nickel Alloy System. Pure iron is probably the best magnetic material if it were not so very costly. Permalloy is favored for telephone cables because of its high initial permeability. Hipernik has no equal at higher inductions, has very high saturation values, and is therefore preferred for most electrical equipment

Improvements such as have been noted for iron and for the 50% range have also been obtained for the $FeNi_3$ range by Arnold and Elmen using pure metals and a special heat treatment, consisting of rapid cooling from the magnetic transformation point (625° C. or 1155° F. for 78.5% Ni). The improved alloy was described in the *Journal* of the Franklin Institute in 1923; it was named Permalloy and its magnetic properties in comparison with those of the alloy when manufactured in the ordinary way are as follows:

	Maximum Permeability	Hysteresis Loss B = 5000
Ordinary 78.5% Ni alloy	5000	400
Heat treated Permalloy	75,000 or more	75 or less

Homogeneity may also (*Continued on page 70*)

HEAT TREATMENT OF ACCURATE PARTS SMALL AND SPINDLING

By Harry Rogers
Metallurgist, Teletype Corp.
Chicago

SELECTION and heat treatment of steel parts used in the assembly of printing telegraph apparatus manufactured by the Teletype Corp. is conditioned by at least three special factors, (a) the complexity of the equipment, (b) the small size of the average part, (c) the use of numbers of long, thin bars and levers. A discussion, with specific examples, will clarify this statement.

Teletype is the trade name of semi-automatic equipment for the sending and receiving of messages by telegraph. The sending machine has a keyboard arranged like the standard typewriter, and can be operated by any typist. The receiving machine is entirely automatic, printing the correct character immediately after the key is pressed at the sending station. Sending and receiving instruments for two-way communication can be mounted on one chassis; then it has the outward appearance of a slightly overgrown typewriter. Inside it has this essential difference — that the linkage between key and type is by electrical circuits rather than by mechanical levers. It is clear that once this electrical linkage has been perfected, there is no limit to the distance which may intervene between the sending key and the printing type.

It will be impossible to give a detailed description of the machine, but a brief outline of its principles will not only be interesting, but will explain some of the allusions to be made hereafter. The main problem is to transmit selective impulses for some sixty different operations over a single circuit. By an ingenious arrangement five selector bars, each having two positions which may be called an "in" and an "out" position, are all that are necessary.

Bars on the sending machine are as shown in the foreground of the photograph on page 37. Five of these saw-like bars with properly cut teeth (each bar different) are set sidewise across the chassis from left to right; teeth just clear the under side of the key bars. These key bars are pivoted at the rear of the machine, and when, for instance, letter "E" is depressed, the bar works down between the teeth on the selector bars, pushing the first, second, and third toward the right to the "in" position, and the fourth and fifth toward the left to the "out" position.

Each of these selector bars is connected by appropriate levers to a pair of contact points,

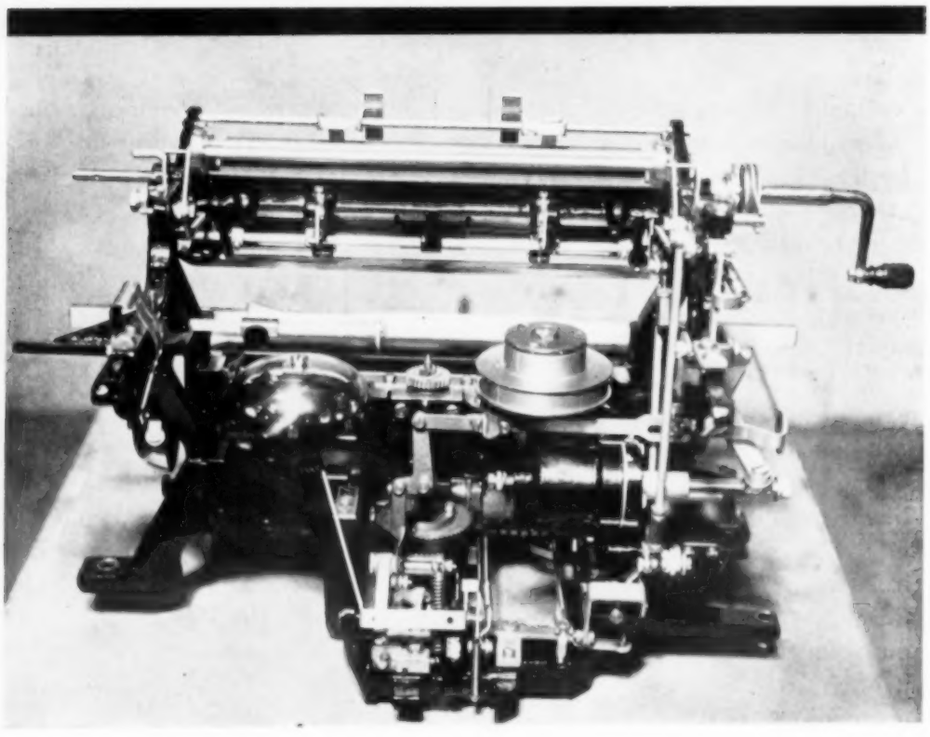
and when the bar is in the "out" position, the contacts are locked so the circuit cannot be closed. Immediately after the letter key is depressed, a clutch throws in and a camshaft is given one complete revolution; this cam has five short segments spaced 72 on centers, one for closing each of the five pairs of contact points. Rotation of the camshaft after the letter "E" is depressed will therefore close momentarily the first, second, and third contacts in quick succession, but the fourth and fifth, being locked open, cannot be closed. The result is that a signal corresponding to "dot-dot-dot-dash-dash" is sent over the wire to the receiving station. After one complete revolution of the cam shaft, it declutches, and the main circuit is open until the next key is pressed. (The camshaft operates at such a high speed that the mechanism can keep ahead of the speediest typist.)

All operations in the receiving machine are driven by a single motor, in step with the cam motor on the sending machine, so that current emanating from the first selector in the sending machine goes through the first of five electromagnets and sets the first selector bar across the front of the receiving machine. For the letter "E," the first, second, and third electromagnets would be energized and pull the first, second and third selector bars over to the "in" position; the fourth and fifth would remain in the "out" position. These bars (a sample is shown in the photograph) have square notches in the upper edge corresponding in position to the ones on the sending machine, and for the case described a clear channel would be opened under the "E" type bar and under that one only. This permits the end of the "E" type bar to drop slightly and a finger on its under edge to catch an operating mechanism which pulls it sharply endwise and throws the type against the paper on the printing cylinder.

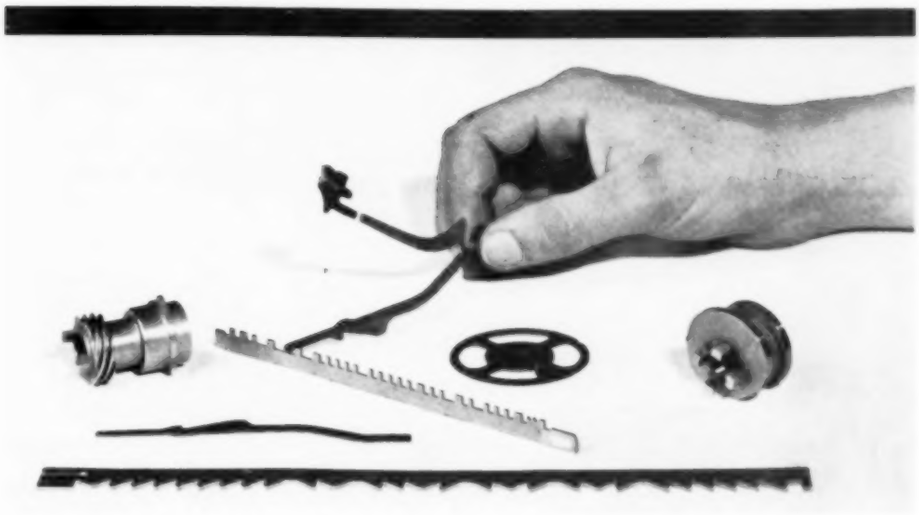
If the reader is interested in permutations and combinations, he can readily figure out that there are 32 possible combinations of five bars, each having an "in" and an "out" position. Twenty-five type bars, each with two characters, will print the upper-case alphabet, numerals, punctuation, and a few special marks. This leaves seven selector locations for such operations as cylinder shift, cylinder turn, return of carriage for new line, blank space between words, signal bell, and synchronization.

We now return to the original statement that the complexity of this equipment has a definite bearing on the metallurgical practice. There are several units, electrical and mechanical, intervening between the typist's finger on the letter key and the type bar at the printing cylinder, and the whole train must be complete in a fraction of a second. These mechanical linkages must be held to close tolerances in order that any looseness at joints or error in form may not be magnified to a point where it interferes

Ninety Per Cent (by Weight) Heat Treated



Size and Shape of Typical Parts of Teletype



Type Bar, Pull Bar and Selector Bar Held in Correct Relationship as in Operation

with almost instant precision. Likewise, the forces acting at many points are rather small, and there must be the utmost freedom of movement. A constant effort is therefore made to control the size after heat treatment, and thus reduce straightening and finishing costs. Some of the parts are made of non-shrinking steel and are relatively easy to handle. Others, such as selector bars, are punched from thick sheet and require hardening on certain portions only — these need special attention.

Nearly all of the machine — perhaps 90% of the weight without motors — is made of heat treated steel parts, despite the fact that the chassis is cast iron, and a few aluminum castings such as brackets are attached thereto. Even small set screws (S.A.E. 1112) are quenched from a cyanide bath to produce just enough surface hardness to prevent marring the head during assembly. A great many springs are used, either to accelerate motion or to return the moving part to its starting position. Coiled springs are made from music wire; flat springs are stamped out of annealed high carbon strip and hardened by us. Special electrical metals and alloys, such as tungsten contact points, are bought from specialists in their manufacture.

Some of the small items going into the machine are made of steel readily available from jobbers in the desired sizes. Since 500 lb. of raw material will make three or four years' supply of some of the tiny parts, it is often impossible to find a small lot of the ideal steel in the correct size. Fortunately, however, the required physical properties can usually be developed by appropriate heat treatment in as many as three or four alternative alloys.

Coming now to a description of the individual parts, let us first confine attention to selector bars and levers punched from thick sheet, which must have hardened teeth and rubbing surfaces. Little or no machine work is done on the profiles; where accurate contour is needed the piece is punched out a little over size, and a "shaving" operation is then performed in a second set of accurate dies, this latter being merely the removal of a small amount of metal from the working surfaces. (Remaining burrs are removed later by a light surface grind, reducing the thickness of the sheet by some 0.005 in.)

Selector bars are made of S.A.E. 1010 steel. On the sending machine the sheet is 0.065 in. thick. It is copper plated before shaving, so the latter operation removes the protective plate on the edges which must be hardened. On the printing machine, selector bars are shorter and are made of 0.050-in. sheet; they are not plated, but wired tightly together side by side in bundles so little of the carburization extends down the sides of the bar.

Bars are carburized by a solid compound in a rotary muffle; about 3 hr. is required for the required case, 0.005 to 0.007 in. deep. Some of the longer bars are then hung endwise from a fixture holding about 40, quenched from a salt pot in oil to a hardness of Rockwell C 58 or more.

Owing to the difficulty of measuring hardness on a surface about 0.05 in. square — and 100% inspection is required — we have sub-

Spindling Parts Hung from End While Heat Treating

stituted a flattened nose for the ordinary ball or cone Rockwell penetrator, and bring this down at standard load on the point of a tooth hardened on both slopes. If the part is too soft the tooth flattens; if too brittle it cracks and flakes.

Selector bars on printing machines (especially those of a design which require teeth on the inside of a curved arc) are quenched individually in oil in a flattening press. Further operations after inspection involve straightening, grinding on both sides so they will fall freely through a slot with 0.001 in. clearance, and nickel plating.

Bars of the above nature carry little stress. The pull bar and type bar, held together in correct relative position in the view, do resist rather high impacts, and consequently are made of alloy steel, preferably S.A.E. 3115. Pull bars (0.050-in. sheet) are hardened in bundles. About 50 are stacked up and tightly wired between heavy end pieces of the same contour. In this way the hardening penetration extends inward from the edges of the part, where the work is done; the sides of the bars, where they come in contact with anything, merely slide freely in a slot. Pull bars are quenched from 1575° F. in oil; the gear end is drawn to 550° in a bath to avoid undue brittleness in the teeth.

Type bars must be flexible enough so they can be bent cold after mounting in the machine—slight adjustments are necessary before the various letters will align in a printed message. For this reason the ends only are oil quenched from a cyanide heat; the type end is drawn back to about 550° so it will not burr if it is struck by another bar. The types themselves are then soldered on the bar end.

Two other long parts have given us much cause for thought. These are the two bars, one rectangular, one round, upon which the printing chassis slides. (The round bar is shown in the front view of the receiving machine, on the opposite page. In this style Teletype the paper supply and the printing cylinder are stationary, and the entire selector mechanism and printing devices notch along, letter by letter.)

Rectangular bar is 3/8 x 7/16 in. in cross-section. It is made of S.A.E. 1020, copper plated, stripped on the top and upper edges of the sides, and carburized about 0.010 in. deep. The round bar is of S.A.E. 1112 steel, 7/16 in. round, with a slot cut end to end. Flanged wheels run on this rod and are located by the slot; the latter must therefore be hardened on its edges. Copper plating all the bar but this slot and carburizing warps the shaft. We then remove the copper plating and quench the piece after a soak in cyanide; this corrects much of the warping, and, of course, gives a hard surface all over. Heating and quenching are done while the piece is suspended vertically from a holder. Most of these pieces now come through so that cold

straightening (of minor amount which does not damage the case) will bring the piece to required tolerances.

The main shaft on the printing machine is a highly stressed piece and is made of S.A.E. 2315 seamless tubing. The 3/16-in. hole down the center serves as an oil channel for lubricating the cams and gears which occupy almost its whole length. Machine work involves turning the shaft to successively smaller diameters, ranging from ½ in. at the large end down to 5/16 at the small, cutting keyways, boring holes for pins and oil passages. The heat treating problem here is to carburize and quench so that the dimensions and concentricity of each surface are maintained within the limits of the finish grind.

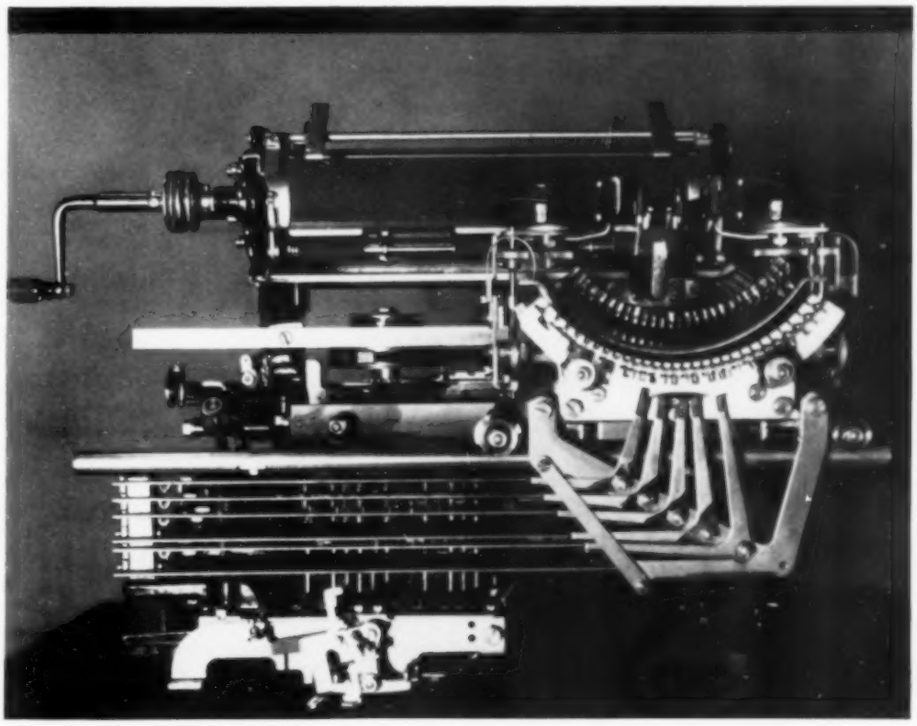
Other parts, such as the flat ratchet wheel shown underneath the man's thumb in the photograph on page 37, are made of a non-shrinking steel (a high carbon medium manganese steel with chromium, tungsten, and vanadium, conforming to Steel No. 1, "National Metals Handbook," 1930 Edition, p. 102). Whenever there are large and sudden changes in cross-sectional area in heat treated parts which must be held to close limits of accuracy, such a steel is almost indispensable. The heat treatment is as recommended in the "Handbook"; parts are hung on hooks or in loose bundles in a salt bath for heating.

Pawls for operating against such ratchets are usually harder (of quenched 1.05% carbon tool steel), for they get more concentrated wear on the ends of the teeth. Many important selector cams are also punched of carbon tool steel strip and hardened.

Minor cams, worms, and gears requiring much machine work are ordinarily made of screw stock. We favor analyses with manganese on the high side — say, 0.70 to 0.80% — for they then carburize deeper and harden better than the lower manganese screw stock or ordinary steels intended for carburizing.

It will be apparent that only the few parts mentioned above out of the several thousand assembled into a single design of apparatus can be described in brief space. Since nearly all of the parts are small, their ratio of surface to mass is high, and it is doubly important to avoid scaling. Therefore, while we have a conveyor furnace with normal atmosphere, most of the heating is done in baths. For this purpose we have an electrically heated oil bath and eight pot furnaces, gas fired, set under hoods so they can be used for either salt or cyanide. Three small rotary carburizing furnaces (American Gas Furnace Co.) are sufficient for the work to be done. Two Homo furnaces are installed for drawing. We have two high-temperature furnaces for tool steel hardening and one for annealing. Necessary oil and water quench tanks have cooling and circulating systems.

Printing Device Moves as It Prints



Selector Bars are Curved and Moved by Levers at Lower Right

ROCKWELL HARDNESS UNCHANGED BY MAGNETIC TREATMENT

By R. H. Harrington
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General Electric Co.
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Testing Hoke Gage Blocks at Pratt & Whitney

MAGNETIC hardening of steel has recently become a topic of some importance with publication of work done by E. G. Herbert. Mr. Herbert has published data in the *Journal* of the British Iron & Steel Institute, 1929, the *Proceedings* of the Royal Society, A, Vol. 130, and in METAL PROGRESS for April indicating that hardened steels and also various non-ferrous alloys may be considerably hardened by rotating the pieces in a magnetic field. Commenting on this matter in a letter to METAL PROGRESS, published in March, Dr. Rosenhain pointed out that no other investigators have published data in support of Mr. Herbert's results, and English metallurgists tend to view this work "with a large degree of skepticism."

It is interesting to note that, although Mr. Herbert claims the discovery of magnetic hardening, magnetic softening or annealing was suggested in the *Transactions*, A.S.S.T., 1924, by S. R. Williams from some tests on hardened steel balls. It therefore becomes of interest to publish data obtained recently by the writer, in consultation with W. E. Ruder, in an attempt to duplicate the work of Mr. Herbert.

Methods of hardening and magnetically treating the steel samples as published by Mr. Herbert were duplicated as nearly as possible by us in the General Electric Laboratory. Our methods of testing hardness were different. Mr. Herbert's results were all obtained by use of the

ROCKWELL "A" HARDNESS OF MAGNETIZED HIGH SPEED STEELS

Time After Test	Quenched and Tempered			Quenched Steel	
	Bar 1 Not Magnetized	Bar 2 Magnetized	Bar 1M Magnetized	Bar 3 Not Magnetized	Bar 4 Magnetized
Original	82.1	82.1	82.3	82.8	80.6
½ Hr.	82.5	82.2	82.2	82.9	80.6
1½ Hr.	82.3	82.2	82.2	82.9	80.9
3½ Hr.	82.4	82.3	82.4	83.2	80.7
1 Hr.	82.5	82.5	82.6	83.2	81.1
1½ Hr.	82.3	82.3	82.7	83.1	81.1
2½ Hr.	82.3	82.1	82.8	83.2	81.0
3½ Hr.	82.5	82.3	82.5	83.3	80.8
4½ Hr.	82.6	82.2	82.4	–	–
7½ Hr.	–	–	–	83.2	81.3
24 Hr.	82.3	82.2	82.1	–	–
96 Hr.	–	–	–	82.6	81.1

Herbert pendulum hardness tester. We used the Rockwell hardness tester. The increase in hardness observed by Mr. Herbert is comparable to an increase from 700 to 820 Brinell hardness, or from 84 to 90 if tested by the Rockwell tester with diamond point and a load of 60 kg. At least, one would expect such an increase to be detectable by the Rockwell machine.

Results of Two Tests

A high speed steel containing 14% tungsten, 4% chromium, and 1% vanadium was cut into samples which were 2 in. long and $\frac{3}{8}$ in. square cross-section.

Test No. 1. Two samples were hardened by quenching in oil from 2375° F. and drawing at 1100° F. In all hardness tests, five readings were taken along each bar and the average of these readings was considered as representative of the whole bar. As hardened, bar No. 1 had a Rockwell "A" hardness of 82 and bar No. 2, 81.7. Seven weeks later the hardness of these bars was respectively A-82.1 and A-82.4. It was felt that these bars could be considered as having reached practical stability.

The bars were then heated together in boiling water in a copper crucible. Bar No. 1 was then removed to be used as a blank for comparison with bar No. 2 which was given the magnetic treatment. Bar No. 2, still in boiling water in the copper crucible, was set across a $\frac{1}{8}$-in. gap between the poles of the magnetizing apparatus in the General Engineering Laboratory of the General Electric Co. (This equipment is in charge of B. M. Smith.) The field was applied and the bar was given one complete turn in the plane of the magnetic poles. Bar No. 2 was then removed and hardness readings taken on both bars at certain time intervals as recorded in the table.

There is no apparent difference between bars No. 1 and 2 that could be ascribed definitely to the magnetic treatment. The hardness readings are within the range of error in testing and the variability of such a heat treated steel. As a further check, bar No. 1 (which served as a blank in the first run) was given the same magnetic treatment as No. 2 and the succeeding hardness tests are recorded in the table under the heading Bar 1-M.

Test No. 2 was performed on bars of high speed steel which had been quenched in oil from 2375° F. but not drawn. Hardness tests were made on both bars after heat treatment; bar No. 3 had a hardness of Rockwell A-82.4, as quenched, and bar No. 4, A-80.8. Seven weeks later the hardness of bar No. 3 was A-82.6 and of bar No. 4 was A-80.6. It was assumed that they had reached a practically stable state. Magnetic treatment was then applied by Mr. Smith to bar No. 4 only, but both bars were heated in boiling water for the same length of time. Hardness tests were then made and are recorded in the table.

The variations in hardness are small and quite possibly due to heating the steel, which had not been drawn to full hardness, in boiling water. There is no difference between bars No. 3 and 4 that could be definitely ascribed to the magnetic treatment.

Conclusions which can fairly be drawn from this work are that the magnetic treatment, as applied to this quenched steel, does not materially affect the Rockwell "A" hardness.

It is possible that the Herbert pendulum hardness tester may be sensitive to changes in a thin surface film. It may be that work hardening of the surface film during the hardness test is a variable factor.

It also seems a bit premature for Mr. Herbert to publish any theoretical explanation of his tests in terms of lattice structure.

At any rate, it would be well for other investigators to follow Dr. Rosenhain's suggestion — that they who may have worked in this field should publish their results.

EQUIPMENT FOR STUDYING INNER QUALITY OF WELDS

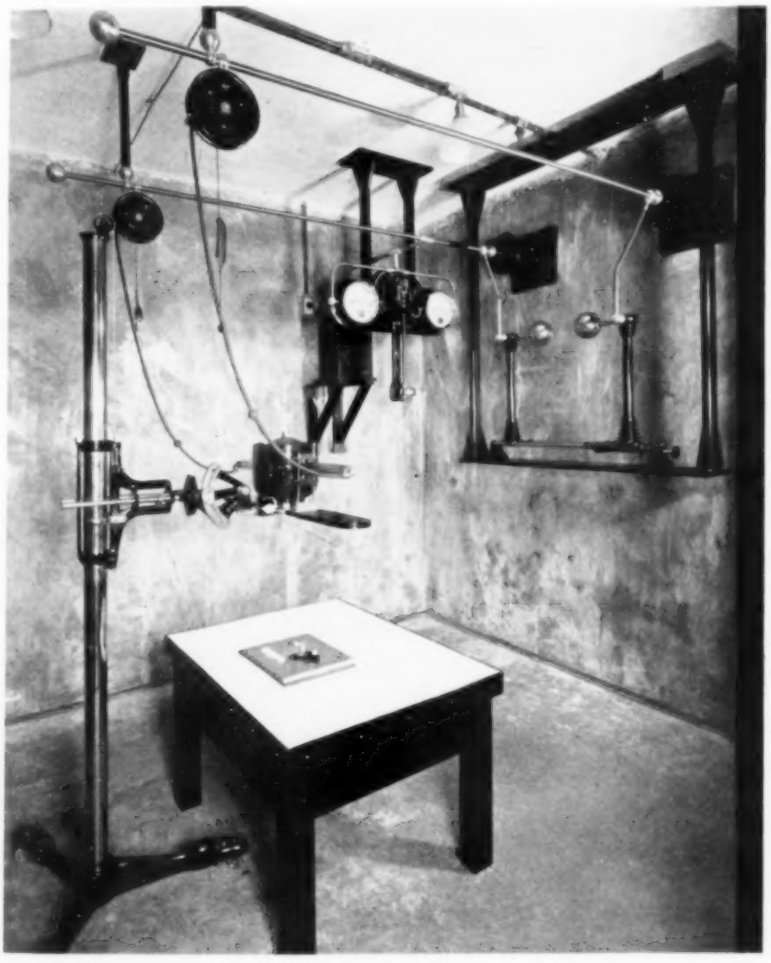
By J. R. Townsend
Bell Telephone Laboratories
New York

WHEN one recalls that the iron blast furnace for making pig iron is a comparatively modern invention, and that the ancient iron furnaces all produced lumps of some variety of wrought iron or steel, it will be apparent that the art of forge welding, or of forming these primitive balls of metal into useful forms on an anvil, is one of the most ancient practices of the metal arts. To go no further back than the colonial times of our own country, hand-wrought iron, which involved the welding of parts together by hand, was much in evidence. The ornamental iron work on the porches of houses which every traveler admires in New Orleans, Savannah, or Charleston, was practically all hand welded. Much of it was originally fabricated in rough forges by Negro slaves. Locks and hinges used throughout the colonies were also made by forge welding.

In recent years many such welded articles have been supplanted by iron castings, for they could be cast more easily and cheaply. With

Operator Views Conditions Inside Lead-Lined X-ray Chamber Through Safety Glass. 200,000-volt tube produces rays which penetrate 3-in. steel

developments in electric and gas welding the tables are now turned. In increasing numbers of instances welding is replacing casting, with great savings in the cost of fabrication. In fact, it is frequently supplanting bolted and riveted joints in structural steel; with correct design a saving in weight of approximately 20% is possible with no loss in strength. Many tests



have shown that welds when properly made are even stronger than the surrounding material. A further economic advantage of welding for structural purposes is that cheap hot rolled structural shapes and plates may be sheared out and welded together without accurate punching or the use of forming tools and gages. Repairs are easily made on all the common metals, and may be done on the job.

Attention was focused on the possibilities of welding while the engines of the Leviathan and other interned German ships were being repaired of the damage done to them when America entered the War. The engines were rapidly reconstructed on the spot by electric and gas welding. A further impetus was given to welding during the War when it was widely used for quick repairs and construction work. Since then, with the development of automatic and semi-automatic welding machines, welding came to be applied to production work. Automobile manufacture (especially body, rear axle, and wheel work) is now largely dependent on welding to achieve low production costs. Welding is being used more and more in building and structural work. Welded pipe lines for gas or oil extend across the continent.

Welding has been employed for years in telephone work to attach precious metal contacts to relay springs. The resistance method has been also used to weld pole pieces of the telephone r e c e i v e r. A recent application of modern arc welding is for steel loading-coil cases. The old cast iron case has been replaced by the new design; two sections of steel are pressed into a U shape and then welded together by an automatic machine.

In Bell Telephone Laboratories a new laboratory has been recently established to study the process. Its purpose is to obtain the specialized engineering information necessary for designing welded parts, to experiment with new welding methods and materials, and to adapt the design of telephone apparatus to welding technique. It contains automatic, semi-automatic, and hand arc welding equipment, oxy-acetylene gas welding and cutting equipment, atomic hydrogen welding apparatus, and an X-ray machine, set up to examine the quality of the welds.

Equipment for gas or electric welding is so familiar, and its ability to weld the common varieties of carbon steel so well known, that no

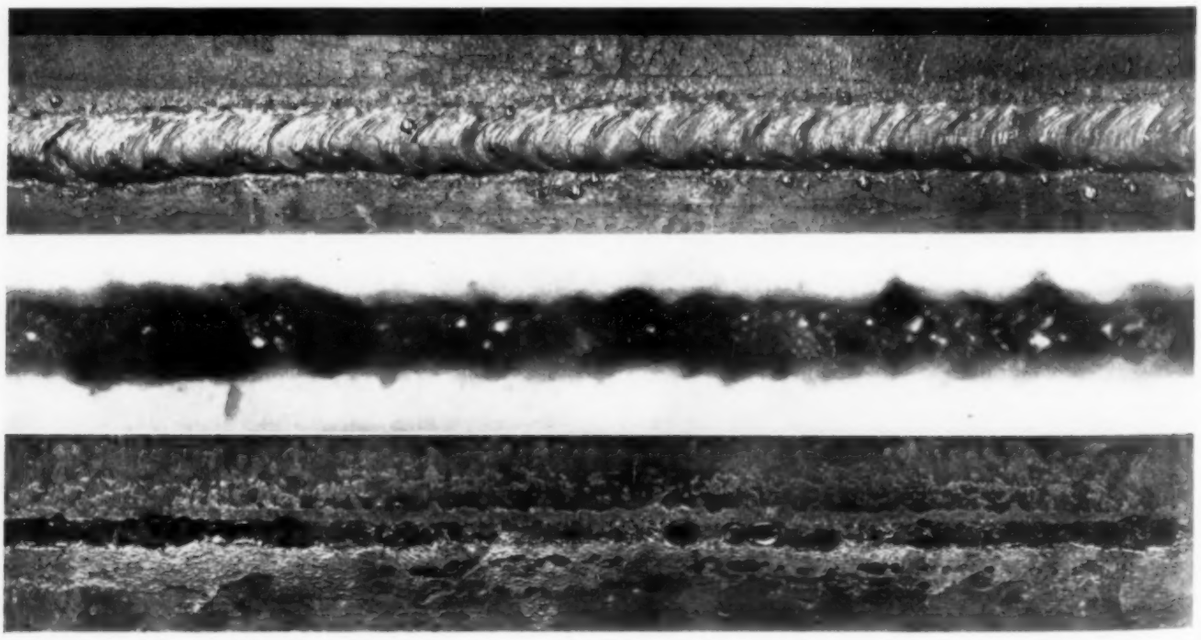
description of it need be given here. Both of them operate by creating a temperature of about 5800° F. at a spot on the seam, so that the edges melt together and incorporate a proper amount of liquid metal from a filler rod. Telephone apparatus uses many metals besides steel, and several of these are difficult to weld together by these methods since they have a tendency to oxidize rapidly. For example, the oxide film that forms on stainless steel or aluminum is so tenacious that it is difficult to get the two pieces of metal to fuse together. A method of overcoming this with the oxy-acetylene blowpipe is to produce an excess of acetylene which reduces the atmosphere surrounding the arc and prevents oxidation of the metal. This method, together with the use of a proper flux for slagging the remaining oxide, is very successful on aluminum.

Another solution of this problem is the atomic hydrogen method. The "torch" consists of two tungsten electrodes between which an arc is formed. Compressed hydrogen gas is forced along each of these electrodes and the two streams meet at the point where the arc is formed. The heat of the arc splits the molecules of hydrogen gas into atoms ("nascent hydrogen") which re-form into ordinary hydrogen as they proceed away from the arc. This molecular change raises the temperature of the region near the arc to approximately 7250° F. and at the same time produces an envelope of highly reducing hydrogen gas at the outside of the flame. With this torch it is possible to weld stainless steel, high speed steel, aluminum alloys, and practically every metal that shows a tendency to oxidize.

The most suitable method of determining whether a weld is satisfactory, without actually destroying it, is by means of the X-ray. An X-ray machine capable of making photographs of steel parts up to 3 in. thick has therefore been installed in the laboratory for this work. The tube has a capacity of 200,000 volts at a current of 5 milliamperes. The whole apparatus is placed inside a room lined with ¼-in. lead. It is controlled from a small antechamber which permits the operator to view the work through a lead-glass window. With some experience the quality and strength of the weld may be estimated from the X-ray shadowgraphs.

The equipment described enables us to carry out all of the necessary investigational work in adapting welding methods to telephone apparatus design. The work not only offers the means of improving upon present methods, but should likewise prove invaluable in bringing out even more extensive applications of welding.

Top, Inside and Bottom of Seam Welded by Machine



HIGH STRENGTH WIRE FOR SUSPENSION BRIDGES

ITS USE

& ABUSE

By Ernest E. Thum
Editor, Metal Progress

EARLY in 1929 news was suddenly broadcast that two very long suspension bridges then approaching completion, had become unsafe and would have to be dismantled. One was thrown across Mt. Hope bay on the main road between Providence and Newport, R. I., the other and larger one (known as the Ambassador bridge) was being built across the river between Detroit and Windsor, on the Canadian side. While these bridges were owned by different corporations, they were both being built by the same contractors, and the main cables (which were proving defective) had been made of a new variety of bridge wire, heat treated instead of cold drawn.

Since this was the first serious trouble that had developed in the construction of suspension bridges within memory of practicing civil engineers, they were naturally keen to know the cause of the trouble. It was evidently concentrated in the main cables. The bridge builders, with commendable courage, proceeded immediately to dismantle the two bridges and re-erect them with cold drawn steel wire such as had stood the test of time. Eventually the structures were opened for traffic on or about the time agreed upon in the contract, a noteworthy feat of organization. The undoubted safety of the bridges, as erected, has dulled interest in the fact that no one really knows why cold drawn bridge wire is eminently satisfactory material, whereas steel wire of the same chemical composition, heat treated to the same ultimate strength, is a doleful failure.

Development of Bridge Wire

Progress is possible when we know the causes of our failures — therefore steel makers, wire drawers and steel users and fabricators generally should be glad to know in what respect the discarded wire was defective. Was it inherent in the material as manufactured? Did it result from the use or abuse to which it was put by the bridge builders. Only when these questions are answered, can new applications of quenched and tempered high carbon steel safely be made.

Suspension bridges are so well known it it unnecessary to elaborate the fact that the loads are carried from a main cable. This cable is hung freely over the top of supporting towers, and is tied back at the ends into massive anchorages. Stresses in the cables between the suspenders are tension stresses — in fact, this main bridge member is made of a multitude of wires laid parallel, and squeezed together and wrapped into a huge round bundle. The individual wires are about 1 5 in. diameter. A built-up member of this kind is evidently inadequate to resist any large secondary stresses, such as bending, compression, or shear. Furthermore, the whole bridge is flexible enough to absorb impacts readily and dampen the effects among a great many members.

Since the stress carried by the main cable is simple tension, and since the member is composed of small elements which can easily be tested in tension, routine tests should clearly indicate the suitability of the material for service. In this instance, laboratory tests ought to duplicate the service requirements; in other cases (for instance, tension tests for structural shapes used for columns) laboratory tests do not duplicate service requirements.

Many American suspension bridges, some of notable dimensions, have been built in the last 30 years according to methods developed by the elder Roebling for the historic Brooklyn bridge. It is an economical type for carrying automobile highway traffic. Specifications and tests for the wire have been more or less standardized; as is shown by the table opposite, this wire has been gradually improved in quality, and the working loads imposed upon it gradually increased. Manufacture is under the closest control and inspection, and the steel is segregated heat by heat clear through to the bridge site. Before the material is accepted tension tests must be made on a piece clipped from each end of each coil of wire, and the ultimate strength and elongation noted; the elastic limit (that is, the load at 0.7% elongation) is measured for each tenth coil. Samples from each tenth coil are also coiled in a close helix, about a mandrel four wire diameters in size. Evidently, the wires must not only be strong but tough. A long history (as history of modern construction goes) proves without question that the cold drawn wire so made and tested is absolutely reliable.

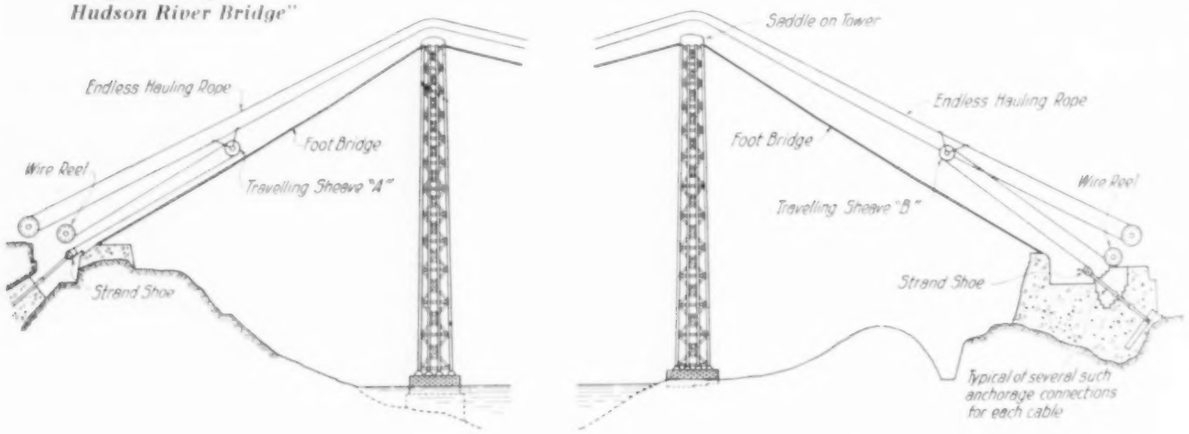
Yet a new variety of bridge wire which passed these and other tests with flying colors, and on the returns was accepted as superior to the conventional cold drawn bridge wire, failed most expensively when erected in two big bridges! This new variety had a much higher elastic limit; the designers believed it could be loaded correspondingly, thus resulting in a notable saving in the cost of the bridge. Yet it failed miserably, although it tested wonderfully. Why this apparent paradox?

Possible Abuse by Erectors

Naturally, this matter attracted much attention at the time, and many hypotheses were advanced to explain the failure. In this series of articles they will be examined one by one.

Method of Spinning Cable

Adapted from "Third Progress Report on Hudson River Bridge"



Comparison of Cables of Important Suspension Bridges

	Brooklyn	Williamsburg	Manhattan	Bear Mountain	Delaware River	Mid Hudson	Mount Hope	Ambassador	Hudson River
Location	East River New York City	East River New York City	East River New York City	Hudson River Bear Mt. N.Y.	Delaware River Philadelphia	Hudson River Poughkeepsie N.Y.	Providence Newport, R.I.	Detroit River	Hudson River Fort Washington (79 th. St. New York City
Date of Erection	1870-83	1896-1903	1901-10	1923-24	1922-26	1926-30	1928-29	1927-30	1927-32
Length of Main Span in Feet	1596	1600	1470	1632	1750	1500	1200	1850	3500
Number of Cables	4	4	4	2	2	2	2	2	4
Number of Strands per Cable	19	37	37	37	61	19	7	37	61
Diameter of Cable in Inches	15½	18⅝	20¾	18	30	16⅛	9⅜	19	36
Total No. of Parrallel Wires in Main Cables	21,432	30,784	37,888	14,504	37,332	12,160	4,900	15,244	105,896
Total Weight of Wire in Main Cables in Tons	3,272	4,344	6,108	1,914	6,626	1,998	700	3,000	28,500
Total Length of Cables Between Anchorages in Ft.	3,578⅛	2,985	3,224	2,640	3,540	3,287	2,650 horizontal	3,639 horizontal	5,212
Total Strength of Main Cables in Tons	44,800	89,200	113,200	47,200	118,000	39,000	–	–	350,000
Diameter of Individual Bridge Wire in Inches	0.187	0.192	0.195	0.195	0.195	0.195	0.195	0.196	0.195
Height of Towers	275'	310'	291'	350'	385'	315'	284'	363'	635'
No. and Dia. of Suspendor Ropes at Each Panel Point	1⅛" and 1⅜"	4-1⅜" Dia.	2-1⅝" Dia.	2-2¼" Dia.	4-2¼" Dia.	2-1⅝" Dia.	4-1⅜" Dia.	–	8-2⅛" Dia.
Specified Strength; Average, lb. per sq. in.	160,000	200,000	210,000	215,000	215,000		220,000	220,000	225,000

The first is this: "That the wire was as good as the tests indicated when it left the manufacturer's plant, but it was abused during erection."

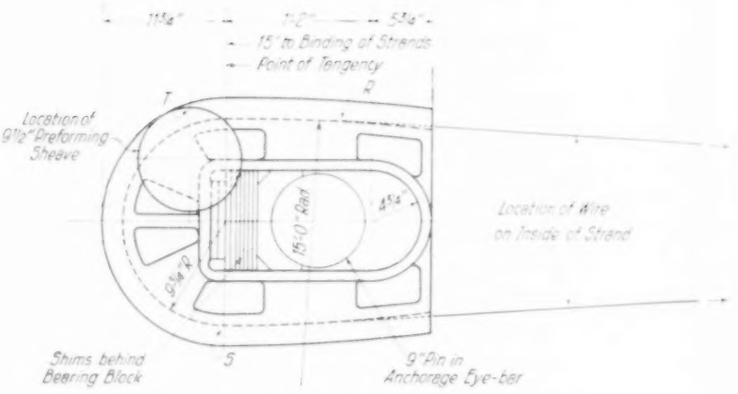
A consideration of this supposition requires a brief description of the method of erection, and some notes on the history of the Mt. Hope bridge. (The Mt. Hope bridge will be described in detail because the trouble occurred there first. Serious trouble was not visible at that date at the Ambassador bridge at Detroit, but the latter used the same wire; the regular production was shipped on order to either site as the erectors required. Obviously, both bridges had the same "disease," were unsafe, and were therefore dismantled.)

Wire may be manufactured in 3000 to 4000-ft. lengths; these are spliced together in a right-and-left hand threaded ferrule, and coiled on 6-ft. drums, each containing about 50 lengths. Field splices of the same sort are made, drum to drum.

The accompanying drawing (adapted from one in a report on the Hudson River bridge) indicates how the cable is spun. The free end of one wire, say on the left shore, is passed around a horseshoe-shaped casting attached to the anchorage, and then looped about a sheave "A" attached to an endless hauling rope extending from shore to shore, via the top of the main columns. As this sheave is hauled across to the right-hand shore and draws the loop along, the wire is payed off the reel. When the sheave finally reaches the far shore it is obvious that it has carried in its wake two wires; the one extends from the fixed end, on the left shore, and is called the "standing wire"; the other has traveled from the reel twice as fast as the sheave, and is called the "running wire". Men at the anchorage on the right shore then adjust the tension on the standing wire until its sag at the center of the main span exactly matches a guide wire, strung across for the purpose. The wire is then clamped down, the loop is taken off the traveling wheel and thrown over a strand shoe at the anchorage on the right-hand shore, and the wheel returns to its original starting point on the opposite shore for another loop. Meanwhile, other workmen on the left shore adjust the tension on the running wire, and throw another loop about the anchorage there. Thus two wires are "spun"; the operation is repeated 175 times, or until a 350-wire "strand" is completed, when the end of the last loop is spliced to the free end at the start. The strand is therefore formed of one endless stretch of wire, looped around shoes tied into the anchorage on either shore.

Only in one important detail was the stand-

ardized erection routine described above modified for the heat treated wire. The latter is much stiffer than the cold drawn wire and the workmen had difficulty in snugging the wire up close to the anchorage shoe. To take care of this, the wire was "preformed by winding it around a $9\frac{1}{2}$-in. diameter sheave, bolted temporarily on the anchorage shoe. On release, the wire "lay dead" at the approximate curvature, $9\frac{3}{4}$-in. radius of the shoe. Strand shoes for Mt. Hope bridge are shown in the accompanying drawing; also the approximate field location of the preforming shoe is indicated.



Scale Drawing of Strand Shoe for Mt. Hope Bridge Showing Location of Preforming Sheave

Cable spinning at Mt. Hope occupied only two months, September and October, 1928. Nothing unusual happened until January, when three broken wires were noticed. Six more were found on Feb. 8, and 11 additional on Feb. 19. They were scattered among the 28 shoes of both anchorages.

Failures at Anchorages

By this time the suspended span had been erected and forms started for the concrete roadway. On Feb. 22, a holiday, 65 broken wires were discovered in the north anchorage, in one strand of one cable. That strand was one-third gone, and by the next day three-quarters of the wires were broken in that particular strand. The situation was grave in the extreme.

All of the breaks so far found were at or close to the point of tangency of the wire to the curve at the shoe (point *S* or opposite, in the sketch at the head of this page).

Repairs consisted of inserting "hairpins" of cold drawn bridge wire around the shoes, splicing them to the broken ends on either side. Form lumber and snow were removed from the structure; nevertheless, new breakages were discovered day by day. For a time it was questionable whether repair gangs, working 24 hours a day, could mend the visible breaks as rapidly as they were occurring, and thus save the bridge from collapse. Hold-back yokes were placed on each end of each cable as soon as possible, and tied back with plow-steel rope, thus relieving the loops about the anchorages of 200 tons strain at each end. Further failures then ceased and by March 15 all known broken wires were repaired — over 330 in number. But obviously the bridge was unsafe and must be dismantled. Upon dismantling many wires were found broken just under the wrappings alongside the steel clamps about which the suspenders were looped. Numerous breakages of this sort were discovered on dismantling the Ambassador cable, even though it had been stressed only one-third as high as that at Mt. Hope, owing to delayed erection of the suspended span.

In appraising the supposition that the wire was mishandled during erection (as well as other hypotheses for the failure), several facts are to be borne in mind:

1. The fractures required time to develop.

2. The fractures were localized. Almost without exception they occurred at or near the point of tangency with the anchorage shoe, or at or near the edge of the suspender clamps.

3. Breakages were found at nearly all shoes at both ends of both cables.

4. In addition to this sporadic breakage, some of the trouble was concentrated; 140 wires were broken in one strand in one cable, and 130 wires in one strand of the other cable at the opposite shore. Other strands lost 16 and 15 respectively.

5. Breakages continued to occur while the dead load was stationary and even slightly decreased.

6. Actual stress in the cables at the time

the first breaks were discovered was about 32,000 lb. per sq.in. (Compare this figure with the designer's allowable unit stress of 80,000 lb., and the yield point of 190,000 and the ultimate strength of 220,000 lb. per sq.in. as given by the ordinary tension test. The wires were apparently breaking at one-seventh their ultimate strength!)

7. Breakages at the anchorage ceased when the stress at the loops had been relieved approximately 20%.

Wire Apparently Not Abused

With these facts in mind, return to a consideration of the hypothesis that the wire was abused during erection. Many circumstances seem to refute this supposition. First, the presence of so many breaks in the Ambassador bridge at Detroit, discovered at the suspender clamps when the cable was dismantled, indicates that the deteriorating action started *after* these clamps were placed, that is, *after* the cable had been entirely spun. Second, if mishandling had occurred at the anchorages at Mt. Hope Bay, the breaks should have been concentrated at one end of one cable, where the offending workmen were stationed. There were no transfers of workmen from anchorage to anchorage, yet many breaks were found at both ends of the bridge. Third, general and gross mishandling would be impossible under the watchful eyes of the experienced inspectors for the consulting engineers. Fourth, "inexperience of workmen" cannot be the cause, for the strand showing the highest number of failures was spun toward the middle of the period, when the crew was functioning with precision.

This very brief statement of the evidence indicates that while the wire was not handled with gloves it was not unduly abused by clumsy workmen in the field. Such a hypothesis might be dismissed with the statement that the same wire manufacturers and cable erection contractor had previously done the work on the Philadelphia-Camden bridge, 1922 to 1926, and later re-erected the Mt. Hope and Ambassador bridges which are now above suspicion.

Other explanations of the failure of heat treated bridge wire, to be considered later, include the ones that individual wires might have been overstressed, or that the steel was unsuitable, or that this or that essential detail of the wire-drawing practice was slighted, or that accidental blemishes not found during routine testing were responsible. It may also be argued that the trouble is inherent in quenched and tempered wire, or that hydrogen brittleness is the culprit, or that the heat treated structure is unstable, or that the defective wire has an extraordinarily low creep limit. There is the question of "static fatigue", and internal strain, and deterioration due to galvanizing. Lastly we must inquire into the ability of hardened steel to resist cracking.

Nearly everyone who had definite information about the failure formulated his own explanation. Some of them will be discussed later in an attempt to arrive at the most plausible one.

Philadelphia-Camden Bridge Across the Delaware River

FINE FORGINGS REQUIRE CORRECT HEATING AND GRAIN FLOW

By Adam M. Steever
Chief Metallurgist
Great Lakes Forge Co.
Chicago

ARTICLES and addresses on forging practices frequently dwell at length on several causes of defects and dissatisfaction. It might be assumed from them that the drop forger's path is so full of pitfalls that he cannot avoid all of them. This, of course, is far from true, so let us approach the problem from the opposite direction, and discuss two very important considerations which make for strong, tough, and satisfactory forgings. These are (*a*) correct heating practice and (*b*) control of grain flow.

Steel is the basic raw material. While the type of steel is usually specified by the customer (and frequently purchased by him) bars of "forging quality" should by all means be insisted upon. The forger is then protected against defective steel due to unsoundness, seams or surface defects which cause rejection of finished parts, no matter how excellent the work which has been done upon them.

In the present article it will also be assumed that the hammers, presses or bulldozers are in good operating condition and the dies are properly made and mounted. With good steel and good forging equipment, the next important thing to check is the heating practice.

Heating before forging is controlled by seven metallurgical factors:

1. Rate of heating,
2. Time at heat (avoid overheating),
3. Maximum permissible temperature to avoid burning the material,
4. Maximum forging temperatures,
5. Decarburization of the surface,
6. Scaling, and
7. Finishing forging temperatures.

For economy, the time of heating should be just sufficient to bring the material to forging heat. For steel of 0.50% carbon and less a minimum time of five minutes per inch of diameter is sufficient for heating bars up to three inches in diameter. Heavier bars require a slower heat. For steels having higher carbon content than 0.50%, somewhat slower rates of heating should also be used. Some steels, especially alloy steels, should even be preheated to avoid rupturing.

It is advisable with larger sizes or irregular shapes to determine the rate of heating for the particular furnace and bar by embedding thermocouples in an axial hole drilled in a sample

bar. Correct heating requires that the bars in the furnace do not touch, and that the furnace is of sufficient thermal capacity.

Accumulation of oxide slag on the floor of the furnace will pit the bars or billets which come in contact with it. In oil fired furnaces, there is more or less coke at or near the burners. This coke, if not removed, may be blown or fall on the hot steel, carburizing it at the point of contact and causing hard spots. Melting and pitting of the material also may result, especially with alloy steels containing chromium.

Overheating is the result of prolonged heating at temperatures which produce excessive grain growth. A fine grain can be restored by heat-treatment, or better, by a combination of mechanical working and heat treatment. A better plan is to prevent it by forging the metal promptly after reaching heat.

Burning of steel is inexcusable, as it only occurs when it is heated to such a high temperature as to produce abnormal grain growth and to destroy the intercrystalline cohesion. Such steel cannot be restored by heat treatment or a combination of mechanical working and heat treatment; it is ruined.

Maximum forging temperatures recommended for safe practice are 200° F., below the solidus curve. Minimum forging temperature depends on the shape and size of the forging, and the time it takes to complete the work. Dr. W. H. Hatfield's suggested maximum forging temperatures are listed below and have been found satisfactory:

0.10% Carbon	2400° F.
0.30% Carbon	2350° F.
0.40% Carbon	2320° F.
0.50% Carbon	2300° F.
0.60% Carbon	2250° F.
0.70% Carbon	2225° F.
0.90% Carbon	2125° F.
1.00% Carbon	2070° F.
1.50% Carbon	1900° F.
3.50% Nickel	2280° F.
3.00% Ni, 1.50% Cr	2280° F.
5.00% Nickel	2300° F.
Stainless Steel	2300° F.

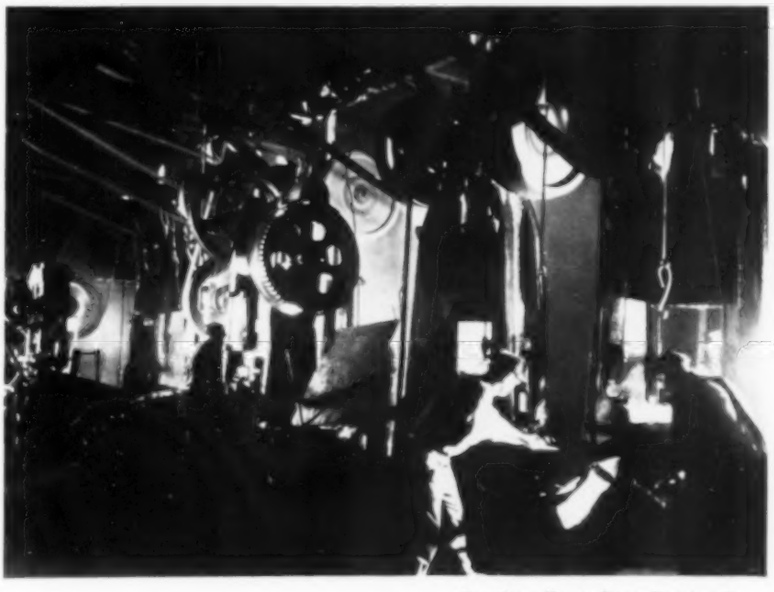
Slight decarburization of the surface layers of steel is probably unavoidable in standard heating furnaces with flames playing over the work. It can be almost eliminated by keeping excess air out of the furnace.

Scaling of materials should also be reduced to a minimum. Scale is responsible for many forging difficulties. It is hammered into the surface and causes machining difficulties; it represents an economic loss of metal and a further loss of time and money to remove it. It reduces the productive life of forging dies due to its abrasive action. As it is desirable to have as little scale as possible, a minimum time of heating should be employed and the free oxygen excluded from the furnace atmosphere. Certain developments have been made recently in furnace design, both in the rotary and the slot type, which control the atmosphere and reduce the scale to an absolute minimum.

Finishing temperature should be as near as possible to the critical range of the steel. This will produce a fine grain in the cold forgings and enable them to respond to heat-treatment without difficulty.

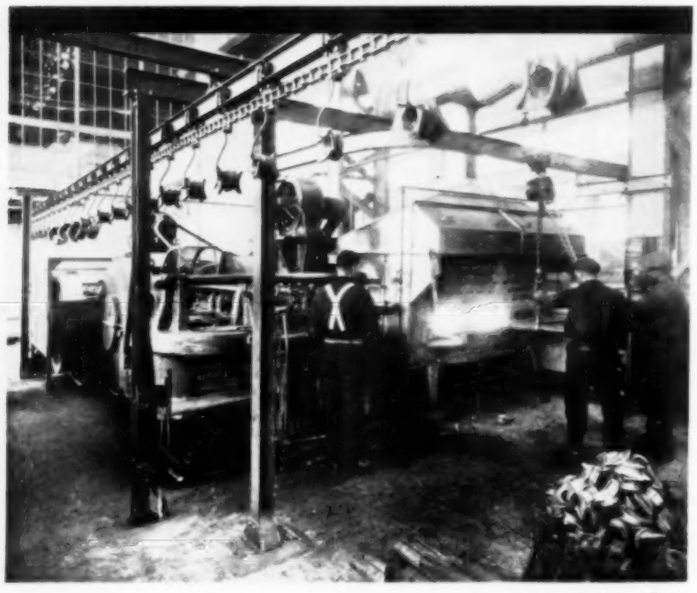
Careless heating is frequently due to an insufficient number of furnaces. This also reduces the output per hammer. The writer is familiar with some shops where improper layout and insufficient furnace space has reduced the production of the hammers by 60%.

Ignorance about the correct rate of heating a given section and the heat absorbing capacity of the steel is also an easily avoidable cause of trouble. For example, less care and time is re-



Courtesy Moore Drop Forging Co.

Forging Machines or Upsetters Have Many Advantages



Courtesy Ford Motor Co.

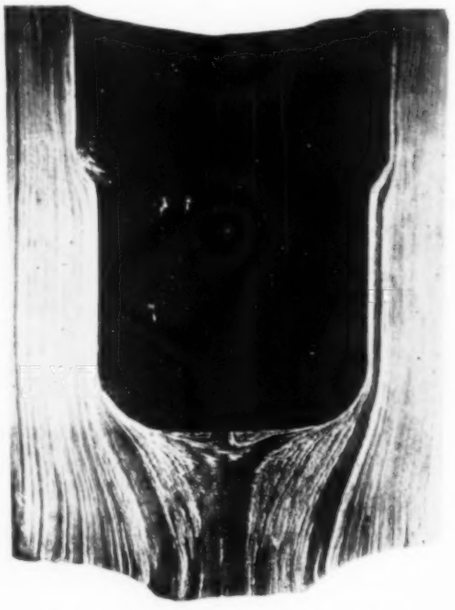
quired to heat low carbon steel than alloys. Even though the average commercial forge shop produces a high percentage of alloy steels, they frequently are heated by the same procedure as carbon steels and invariably trouble ensues. Usually the steel becomes overheated and sometimes burned beyond recovery. The metallurgist and heat treating superintendent know what a large amount of unnecessary work is placed upon their shoulders as a result. While the critical points have not changed in the overheated materials, the response of the steel to grain refining treatments is so reduced that it is difficult to gage correctly the time-temperature program. It is therefore often necessary to retreat overheated forgings. Multiple heat treatments may sometimes save parts that have been overheated locally, but this of course is expensive and avoidable by proper care.

From experience we have learned that one of the important factors in the production of a satisfactory forging is correct heating practice, and by this I mean sufficient *time* at the correct temperature to heat the stock uniformly to the center. In the past it was often the rule to give the furnace as much heat as it could stand, in an effort to increase the production proportionately. Actually what took place was a heavy scale on the surface of the stock, a decreased speed of heat penetration, and an increased cost for fuel consumed.

Because of the greater ease of temperature control, better control of the induced air, better control of the time cycle for heating the materials, and better fuel efficiency, a continuous type of forging furnace equipped with pyrometers and automatic temperature control should be installed wherever possible. But without discussing the design of forging furnaces, which is a large subject in itself, let us now pass on to the second principal factor in the production of tough satisfactory forgings, namely, control of grain flow.

In order to secure maximum strength and durability, especially against shock and high stresses, forgings should be so formed that the flow lines are in the correct position. In simple parts, subjected to high stresses, grain flow is not so important.

Designing engineers are surprisingly ignorant about this subject of grain flow. Many forge men disregard it, even though metallurgists have frequently discussed it. What follows must be regarded as a group of generalities, gained from experience, for the subject has not as yet received much precise scientific investigation, and at present exists in a state half way between accurate knowledge and traditional practice.



Pierced Bar, Sectioned and Etched to Show Fiber or Flow Lines

It is well known, of course, that the essential structure of steel ingots is crystalline. From the surface inward the crystals are more or less parallel and a fracture there reveals a somewhat columnar structure. In the core the arrangement is usually helter-skelter. Such structure may be revealed by deep etching a cross section and examining it.

Where the crystals abut against each other, a non-crystalline cementing material exists, and in these surfaces some of the unavoidable impurities in the steel, such as phosphorus, tend to concentrate. Crystals of steel in the ingot are generally large and their size will depend upon the rate at which they are cooled from a specific temperature (which varies somewhat with the composition of the steel), but depends more upon the size, shape and mass of the mold.

What is important to note in this connection is that the ingot has no "directional properties" — that is to say, if test pieces are cut in all directions from the central zone of a sound ingot, it will be found that the results obtained (tensile strength, ductility, impact strength) are the same in all specimens within the limit of experimental error.

It must be admitted, however, that the average size of these crystalline grains in the ingot is rather large, and, further, that experience proves beyond doubt that other things being equal, the finer the grain size the tougher will be the material. It would almost seem that the larger the size of all metallic crystals, the less is their adhesion and in the same degree their general mechanical properties. It is evident therefore that small crystals are most desirable, and it is for this reason that hot and cold working and heat treating is done. Hot work breaks up the crystals and elongates them into long needle-like shapes (if the final form is a bar) or flat pancakes if the final form is a plate. When this is done, the directional properties usually become important. When steel has been worked, the direction of the "grain" or "fiber" must be given due attention if the best possible properties and service are to be obtained from the material.

One type of forging which exhibits these directional properties is heavy walled tubes, like hollow shafts, gun-tube forgings, and high pressure cylinders. Gun forgings, for instance, are forged from a pierced ingot over a mandrel. A more or less equi-axed crystal in the ingot becomes flattened out into a narrow oval platelet. If three test pieces are cut from the tube, one parallel to its axis, another tangential to the barrel, and the third in a radial direction, the three will have about the same tensile strength, but the elongation, contraction in area and impact strength will be highest in the longitudinal direction, less in the tangential (where the working stress in a gun tube is highest) and least in the radial direction.

An enormous amount of consideration was given this matter during the War, but apparently no reliable method of avoiding this tangential or transverse brittleness has been discovered. Commercial heat treatments cannot correct it. The proof of this statement is contained in such articles as the ones on "Ghosts in Large Forgings" by Harper and Stein in METAL PROGRESS last July and August. Other proof is in the attached table of comparative tests, longitudinal and transverse, of smaller forgings made for the automotive industry.

It is thought that these directional properties are due to the difference in properties of crystals and non-crystalline filling material in the original ingot, but whatever the reason for this grain flow of fiber in steel, it follows the direction of rolling and runs parallel with the length of a forging billet. It has been compared to a plank of wood, in which the grain of the wood runs in the same manner. In selecting floor joists, the carpenter takes wood in which the grain on the under side runs parallel to the edge. This example is to point out the importance of insuring as far as possible, that

LONGITUDINAL AND TRANSVERSE PROPERTIES OF TYPICAL FORGINGS

	S.A.E. 1020		S.A.E. 1035		S.A.E. 2330	
Oil quenched from	1650°F.		1550°F.		1510°F	
Air cooled from	1150°F.		1150°F.		1150°F	
Tensile properties	With Grain	Across Grain	With Grain	Across Grain	With Grain	Across Grain
Tensile strength	71,600	70,500	93,000	91,000	135,000	130,000
Elastic limit	43,000	49,200	56,000	53,700	112,000	108,000
Elongation in 2 in.	35	22	27	15	20	10
Reduction of area	60	40	50	35	50	30
Izod impact, ft-lb.	70	20	20	5	55	15
Brinell hardness	143		192		217	

Fiber in Such Pieces Parallels Surfaces

Courtesy U. S. Naval Gun Factory

tension stresses fall longitudinally with the direction of flow of the material, and that shearing stresses fall cross-wise.

Forgings possess a very distinctive direction of flow of their component crystals. Since the first essential in a forging is that it should not fail in service, it is important that stresses should be carried in such a direction in the metal as will be most resistant to failure. Stated in another way, the toughest metal should be placed where it will carry the heaviest loads.

Consider the forging of gear blanks, which has been discussed many times in this connection. It may be drop forged from a flat bar longitudinally. It may be drop forged by the upset or slug method. It may be formed in a forging machine or upsetter.

When the blank is forged from a flat bar half of the teeth will cross the grain and approximately half will be with the grain.

When the hammer upset method is employed, the slug of steel is set on end. The grain is vertical. The slug is then flattened into a disc, the disc is then placed in the die impression and finished. If a forging machine is used it grips the shank of the material and by several passes or operations shapes the protruding portion into the desired shape. In these two methods the grain of the material is spread out and takes up a direction which is approximately radial from its center. A cross sectioned and etched gear then possesses a grain which is similar to a spoked wheel. These grains run out into each individual tooth and each is equally tough.

If some gear teeth are cross grained at the root, excessive stresses will probably cause failure. One reason is that the impact value of the material is low when the fibers are parallel to the fractured surface, and the other is that a tooth with a transverse grain must withstand all the stresses whereas, when the grain is longitudinal, part of the stress is carried down into the center portion, somewhat as though the grain in the tooth were actually tied into that in the center of the gear.

While it is realized that the above discussion of "fiber" or "grain" of metal may leave much to be desired in the way of scientific exactitude, it is important to remember that the most satisfactory forgings for high duty parts have been manufactured by modifying the dies so that the grain (as indicated by pickling a cross sectioned forging) is properly disposed to carry the loads and does not run out to the surface at any place near a stressed region.

Fiber, while it is probably due to soluble impurities or segregated impurities of less than microscopic size, is a matter entirely distinct from dirt or non-metallic inclusions in the steel. The latter are a cause of a certain number of forging failures but from experience gained from many metallurgical investigations on forgings that have failed in service, I am of the opinion that most of them are due to excessive impact or to fatigue, and that a majority of them have started from sharp corners or from tool marks left by the machine shop.

First class forgings are the result of close cooperation between steel manufacturer, forger, designer, and machinist. With the continued cooperation of intelligent men in these various callings, we can without question manufacture forgings, assured of a superior metallic shape. This will please all concerned.

LETTERS FROM METALLURGISTS IN AMERICA & ABROAD

NEW YORK — TIN is one of the indispensable metals of modern industry which has suffered much from violent changes in demand, production and price. Several attempts have been made to bring these fluctuations under control, but until recently the efforts have been futile, principally because the sources of the metal are numerous and scattered, each producing but a relatively small amount yearly. For a similar reason there could be no serious effort or research expended by the producers on the problems of improving the commercial metal or of widening the uses.

Tin Producers to Study New and Old Uses

Notwithstanding these previous failures a new attempt was made in 1930 to meet the unusual conditions arising from a world-wide contraction in demand. The fortunes of the tin industry are of such importance to the principal producing countries that their Governments decided to intervene with such actions as would be necessary to insure the successful outcome of the efforts already initiated by the producers. Consequently the International Tin Committee was formed early last year by delegates appointed by the Governments of Malaya, Nigeria, Dutch East Indies, Bolivia, and Siam, which together have control of approximately 95% of the world's production. A carefully devised quota scheme has succeeded in limiting the production in accordance with decreased consumption. Some difficulty was encountered at the outset in allocating, among the more than 1500 separate mines in Malaya, the quota assigned to that country.

One important and long neglected activity being carried on under the control of the International Tin Committee is that of research and development, for the support of which a fund has been subscribed by the quota governments. This work had already been under way for a period of more than two years under the name of Tin Research & Industrial Applications Committee, a fund for its operation having been provided by the tin producers. Investigations will be carried forward along the same lines, with the assurance of adequate financial support. The undersigned is the representative in the United States of this Research and Development Section, and is prepared to cooperate with American tin users in the solution of problems involving the industrial applications of tin.

Every effort will be made to serve consumers in a helpful way. It is proposed to carry on much of the investigative work in the United States, as befits its importance as a major consumer, and to coordinate such work with American research activities.

L. J. TAVENER

PARIS, *France* — In METAL PROGRESS for August, 1931, the writer discussed briefly the hardening of quenched metallic alloys by precipitating a constitutent *M* in a suitable degree of fineness from a supersaturated solid solution. This constituent *M* is often a definite chemical compound, hard itself, and sometimes *M* is a solid solution enriched with such a chemical entity.

Precipitation Hardening at 1500° F.

For instance, take the iron alloys: Ferrites (solid solutions of alpha iron) and austenites (solid solutions of gamma iron) are hardened by precipitation of either definite compounds or solid solutions formed of iron or some other of the alloyed metals with carbon, nitrogen, phosphorous, boron, aluminum, beryllium, or copper. In the issue mentioned, about a year ago, the general appearance of the time-hardness curves was sketched for increasing temperatures. There seems to exist a zone of temperatures wherein hardening occurs; higher temperatures cause tempering (coalescence of the precipitate). These zones succeed one another and partly overlap. Tempering generally begins with mild temperatures — below 1200° F. This explains why structural hardening has been employed to improve the mechanical properties of parts working at moderate or atmospheric temperatures.

It is of course desirable to know whether similar actions take place in strong alloys at temperatures at or above those demanded by the chemical, petroleum and power industry for high pressure working.

Such results were obtained by the writer jointly with Messrs. Pretet and Jolivet, while studying austenites containing tungsten or molybdenum with or without other metals or elements (such as carbon, chromium, or vanadium). To simplify the matter, let us consider the iron-nickel-tungsten alloys containing no other element, thus eliminating all complex cementites or carbides, which, if present, might also harden the structure.

When the tungsten content of these pure alloys exceeds a certain value (which is a function of the temperature and the nickel content), then some constituents which we call *M* appear in the gamma solid solution. Provisionally these have been called tungstides or solid solutions rich in tungstides.

Solubility of constituent *M* in austenite was studied by means of dilatometric and micrographic analysis, and showed that solubility increases with temperature. Such austenites may therefore be supersaturated by heating at a very high temperature (up to or even beyond 2400° F.) and rapid cooling. Precipitation becomes obvious at 1200° F., and is rapid while reheating between 1550° and 1750° F. (depending upon the alloy analysis). This gives us an alloy which hardens at a high temperature. At higher heats the coalescence of the precipitate and later its re-solution gradually bring the hardness of the alloy back to that of the solid solution. The general appearance of the time-hardening curves at the various temperatures is the same as we showed in the general discussion last August.

Hardness of these alloys at heat was measured by the proportional limit in a compression test. As an example, take pressure tests (made in the temperature zone where a fine precipitate is relatively stable) on two alloys: *A* containing 30% nickel and 25% tungsten and *B* containing 30% nickel and 30% tungsten.

PROPORTIONAL LIMITS IN COMPRESSION

	Alloy A	Alloy B
As cast	22,000	38,000
After 24 hr. at 1550° F. Tested at 1475° F.	48,000	53,000

It must be noted that deformation of the hot alloy, by forging, aids the precipitation and consequently the hardening, just as cold working light aluminum alloys (hardened and not

tempered) speeds up the hardening. This phenomenon is also a general one.

The presence of other elements such as carbon, manganese, or chromium changes the conditions and the possibilities. It may decrease greatly the tungsten and molybdenum content necessary for a desirable amount of structural hardening. It is enough to recall what the writer remarked more than ten years ago; namely, the possibility of studying, by means of slow cooling, the tungstides and the molybdides of steels containing 0.1 to 0.2% carbon and 5% tungsten or 1% molybdenum.

Utilization of these phenomena opens a wide field for applications which require metals at high temperatures.

ALBERT PORTEVIN

Value, Scope and Interchangeability of Mechanical Tests

LONDON, *England*—BOTH in this country and at the Congress of the International Association for Testing Materials at Zurich last September there has been much active discussion on the question of proper application of mechanical tests. Some further contributions to this subject were made at the recent meeting in London of the Institute of Metals where a whole session was devoted to the discussion of "The Testing of Castings." The tensile test has become so well established that it is probably idle to raise any question as to its continued use in the future; none the less, it is increasingly realized that it is quite unjustified to speak of the "tensile strength" of a material as its "strength" in general terms.

Put in another way this simply means that tensile strength alone is not a measure of the quality or usefulness of a material even if a sufficient degree of ductility, as represented by elongation figures, is retained. Like Brinell hardness, tensile strength represents a function of a whole group of properties. Individual members of this group may be much more important in some cases than in others. By way of explanation of this view we may quote such properties as resistance to wear or abrasion on the one hand and resistance to alternating stresses and to the combined effect of alternating stresses and corrosion on the other.

On these grounds the writer takes this view: For the majority of purposes the results of a tensile test should rightly be regarded as of the nature of tokens or indexes showing that the material in question falls within the limits of properties that experience has shown to be desirable and sufficient for certain purposes. It must, however, be borne in mind that when we rely upon the correlation of what is after all an arbitrary form of test with the results of long practical experience, we do so on the basis of a number of tacit assumptions. One of these is that the chemical composition of the material also lies within certain well-defined limits, because if such limits are not retained it is perfectly possible to produce material giving results in a tensile test which are very similar to those previously obtained, yet having widely different properties in other directions.

This is probably the correct answer to the contentions that in specifications nothing beyond the mechanical properties of the material should be specified, and to limit chemical composition in addition to test figures is an unnecessary restriction upon the manufacturer. Such a view would be sound if the ordinary tests could really measure those mechanical properties which are desirable and necessary in construction. Our knowledge of the mechanical properties of materials, however, has now developed so far that any such assumptions in regard to the tensile test cannot possibly be sustained.

The growing recognition of this fact, while it has not led to any serious questioning of the value of the tensile test, has necessarily increased the importance attached to other forms of testing. Those principally concerned are the determination of the fatigue range and of the notched-bar impact value. Those who have studied the investigations of fatigue (carried out in England, Germany and America) cannot

doubt the value of the information furnished by a series of fatigue tests properly conducted and carried to a sufficient number of reversals of stress, especially if they take the form of or are supplemented by a corrosion fatigue test of the type developed by D. J. McAdam in America. Unfortunately, tests of this kind are lengthy and it is generally considered, at all events in this country, that they occupy too much time to be applied in routine industrial practice.

Many attempts have been made to find quick methods of determining the fatigue limit, especially in steel, but unfortunately none of them have proved permanently satisfactory. The difficulty appears to lie in this fact: While these quick methods give perfectly consistent results with those of long duration tests when the material is of good quality, the deleterious influence of defects acting as "stress raisers" is not readily indicated by anything but a true endurance test. A tempting way out of the difficulty is to rely upon the ratio, which generally lies between 0.4 and 0.5 for steel, of the endurance limit to the ultimate tensile strength. Unfortunately, this ratio also is liable to be seriously affected by the presence of defects, and fatigue limits calculated from it would be wrong if applied to unsound material. A stringent examination of the material for unsoundness by microscopic and allied methods should then furnish a safeguard, since the presence of stress-raising defects can generally be definitely ascertained. In Great Britain there is still considerable reluctance to include examination of the structure (whether by microscopic methods, macro-etching or nature-printing) in any form of specification, although in industrial practice it is often done.

Another form of test which has received much discussion of late is the notched-bar impact test. The old controversy, which raged during the years of the War, as to the merits of this test, has long since died out. In a discussion on this subject at the Zurich Congress it was almost unanimously recognized that this form of test gives a good indication of satisfactory or unsatisfactory heat treatment for any one type of material, although it should not be used for classifying different materials in any order of merit. Actually, discussion has centered more about the manner in which the test is made than its value or interpretation.

In the present state of our knowledge it is obviously impossible to compare results obtained with specimens of different dimensions. The necessity of standardization, both national and international, becomes increasingly evident. Unfortunately, several countries have already adopted a definite practice; in this country a standard notched-bar impact test has been adopted by the British Standards Institution (formerly the British Engineering Standards Association). In Germany a standard has been tentatively put forward, differing only slightly from the British, but even this slight difference is important and would render the results incapable of satisfactory intercomparison.

The difficulty of changing from one standard to another or of adopting a common international standard lies in the fact that it would make it impossible to compare future test results with the immense mass of accumulated data already available in each country. Since, in this case also, a test has essentially a value which accrues from prolonged correlation with service experience, those responsible are naturally reluctant to change the basis of such a comparison and thereby, in a certain sense, to sacrifice their past experience.

A way out has been suggested, as the result of the Zurich discussion: Each country, while retaining its own standard test piece, should also standardize a common international one. For a time both test pieces might be used side by side in each country until sufficient correlation has grown up around the international test piece to allow of its sole future use. This procedure implies a good deal of apparently unnecessary duplication of tests, possibly over a period of years. In the writer's opinion, however, this is a small price to pay for the ultimate benefits of international standardization.

WALTER ROSENHAIN

Most Iron Is Reduced Below Tuyere Level

BOCHUM, *Germany*—DURING 1929 to 1931 an extended research into the chemical reactions of iron smelting was conducted on the blast furnaces of the Bochum Steel Works, of which the writer is supervising engineer. The furnaces investigated were making basic iron at the rate of 550 long tons per day. Blast pressure was about 10 lb. per sq.in., temperature about 1200° F. Principal dimensions of the furnace lining are: Hearth, 13 ft. diameter by 7 ft. deep. Bosh widens out upward for 17 ft. to a diameter of 23 ft. Shaft then contracts uniformly to 13 ft. diameter at an elevation 71 ft. above the iron notch.

Samples of gas and solid matter were withdrawn at four levels, namely, at the center of the slag notch, 3.2 ft. above the hearth bottom, an auxiliary slag notch 4.5 ft. above the hearth bottom, the eight main tuyeres 7.2 ft. above the hearth bottom, and the eight auxiliary tuyeres 6 ft. higher up. Samples were taken while the tuyeres were on blast and while they were plugged; the latter represented conditions existing midway between tuyeres.

To take the samples a water cooled steel spear was thrust through a tuyere or slag notch until a hole on its top surface was located at the desired distance from the axis of the furnace. Gases were withdrawn and analyzed and a sample of the descending solids collected in a long steel spoon contained in the tube and drawn slowly backward under the above-mentioned hole. Many tests were taken from a furnace in a relatively short time, and these were correlated with the analyses of the iron and slag as tapped and the slag remaining on the hearth. About 1100 tests were made and completely analyzed by the laboratories of the company's fourteen plants.

The so-called salamander (*Stille Mann* or dead man) which is the consolidated core of the charge, begins above the level of the main tuyeres, at which it is roughly 6 ft. in diameter. Here it consists of ore and coke. Below that level it widens out in a sugar-loaf form, and rests on the hearth. At the bottom it consists of coke only. This dead material is somewhat more porous when the furnace is making foundry iron than when making basic iron on account of the larger amount of coke in the charge.

From the analyses of the metal withdrawn with the various samples, it appears that its carbon content reaching the upper tuyere level is about the same as in the tapped iron (about 4.1% C). As this iron passes through the incoming blast, the carbon is reduced to about 1%, but this loss is recovered by the time it reaches the slag tuyere level. Manganese acts in essentially the same manner. Phosphorus is also oxidized in front of the tuyeres, but is again reduced and recombines with the iron between the main tuyere and slag notch level. Silicon is reduced almost entirely in the hearth, for only there is the temperature sufficiently high. Sulphur, derived 70% from coke and 30% from ore, may run as high as 0.30% in front of the tuyeres, yet the iron on tapping contains only 0.02%.

Slags withdrawn from the region in front of an operating tuyere will contain 30 to 50% iron; in front of a stoppered tuyere this is about 12%. At the level of the slag notch it has dropped to 2%. Manganese and phosphorus oxides in the slag are highest directly in front of the tuyeres and diminish toward the center of the furnace. Since the silica and alumina content in all samples is less than that of the tapped slag it is assumed that the coke ash (which furnishes the difference) is dissolved in the hearth.

Free oxygen is found 2 ft. in front of the tuyeres. Carbon monoxide reaches its maximum about 15 in. from the wall; none was found 3 ft. inside. Carbon dioxide first appears after CO has passed its maximum; at the center of the furnace (in front of tuyeres) it comprises 40% of the gas.

Heat balances and material balances were computed for the furnace. Representative values were published in *Stahl und Eisen* late last

year (Vol. 51, No. 48). A surprisingly large amount of manganese, silicon and phosphorus is reduced below the level of the cinder notch—that is, at the very bottom of the furnace. The small amount of all reactions occurring above the tuyeres is due to the high speed of driving.

We were unable to determine whether the oxidation of iron and refining of carbon from the remaining metal which takes place immediately in front of the tuyeres is a necessary evil or has a favorable influence on certain reactions. The blast furnace operator is more interested in a uniform condition of porosity throughout the entire shaft, and in the heat concentration in the lower part of the furnace.

JULIUS STOECKER

Hot Pearlitic Cast Iron from Rotary Furnace

TURIN, *Italy*—PREVIOUS letters have described some of the economic considerations which have caused the rapid installation of rotary melting furnaces in European iron foundries. Other compelling factors are their great technical advantages, such as their ability to produce iron of exact composition, low carbon content and with high superheat—qualities required for nearly all high grade castings.

In this respect the cupola is definitely inferior. In fact, only the crucible can compete with the rotary furnace, but the costs of crucible melting are far too high for the great majority of purchasers. It may be questioned whether the reverberatory (or air furnace) is not the equal of the rotary furnace, and this will now be considered.

A quiet metal bath can be highly superheated (say to 2900 F.) in a reverberatory furnace only when the bath is very shallow. Even then a great difference of temperature between the top and bottom layers of the bath cannot be avoided. To obtain a very hot metal in the ladle the surface of the bath in the furnace must be strongly overheated. Apart from the fact that, under these circumstances, the fuel economy falls to very low figures, high top temperature and the large surface of the bath cause many well known difficulties.

First of all is the enormous increase of oxidation, due to the action of the flame on the metal. Heavy metal losses, especially of silicon and manganese, make it practically impossible to keep the composition of the iron within the narrow limits now generally required. Absorption of sulphur from the furnace gases is also greatly enhanced.

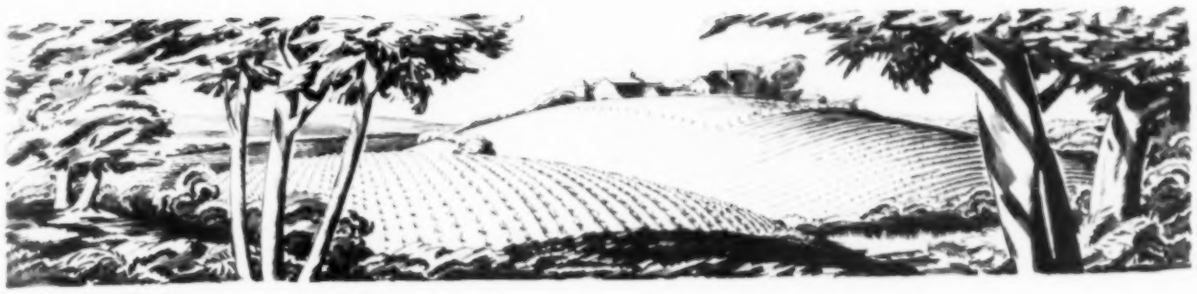
On the other hand, the temperature of the bath surface cannot exceed certain limits, in practice set by the rapid destruction of the furnace roof. Furthermore, it must be remembered that the average temperature of the metal in the ladle will be much lower than the highest surface temperature which can be reached in the furnace.

All these technical inconveniences are absent in the revolving furnaces. As the surface of the metal is continually renewed, and the temperature of the whole bath equalized in all its parts by the mixing effect, the hearth need not be heated above the temperature required for the metal when tapped in the ladle. For the same reasons, the bath can have a comparatively small surface and a correspondingly great depth.

Finally, the metal can be heated to a much higher temperature without damaging the roof. In fact, the revolving furnace has no real roof, for the refractories forming the roof at a given moment are covered by the metal one minute later and protected against the direct action of the flames. Thus the refractory lining of the furnace never reaches a higher level than the average temperature of the metal bath.

With the rapid increase in the use of low carbon, low phosphorus, and special iron castings, the practical value of this technical superiority is becoming greater every day.

Especially good results have been obtained with the revolving furnace in the manufacture of pearlitic and other high quality iron castings derived from the original *(Continued on p. 66)*



AT THE TOP OF THE HILL

A LONE figure in overalls surveys the fields of his labor. Freshly planted rows point their even lines around a gently rising hill. Seemingly the world and its people are far away. But this man is not alone!

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Undoubtedly a great factor in the continued progress and improvement of telephone service is the intangible but real spirit of service that has become a tradition in the telephone business. This spirit expresses itself daily and in any emergency. And behind the army engaged in giving service is the pioneering help of a regiment of five thousand scientists and technical men, engaged in the sole task of working for improvement.

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CONCENTRATES FROM THE LITERATURE

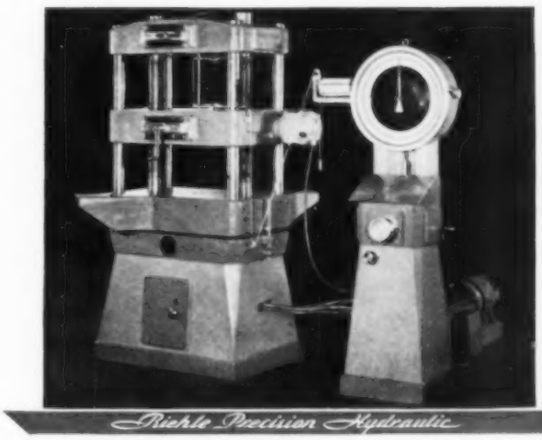
FOURTH report on the **"HETEROGENEITY OF STEEL INGOTS"**, in the form of a 250-page pamphlet, has been made to the British Iron and Steel Institute. It attempts to coordinate the results of the fundamental studies and the examination of the 32 ingots previously made, with a further study of 27 two-ton ingots made under controlled conditions. Even yet "the time has not yet come when an exhaustive analysis of the experimental results of the investigation, in the light of theoretical researches, can be achieved." An idea of the general progress made may be gained from a particular statement: That three general modes of distribution of silicates have been determined by analytical work; theory would indicate that these three modes are due to two opposing influences, (*a*) settling of small particles and (*b*) upward movement of particles of low viscosity, accumulating others by contact as they ascend. Nature of these particles is determined by the deoxidation process. The general problem of gas in steel is considered in a lengthy presentation of the principles involved in the making of rimming steel. Manufacture and properties of the ingot mold also have been studied in detail.

STEELS of almost identical composition and manufacture vary greatly, heat to heat, in their sensitivity to slight variations in heat treatment and to the embrittling effect of cold work and subsequent aging. H. W. Graham, in a thoughtful paper before the American Iron and Steel Institute last month entitled "A Modern Conception of **STEEL QUALITY**" said that this varying sensitivity is probably related to the colloidal content of oxygen and nitrogen. The physical condition of these elements and their compounds is determined by the nature of the original pig iron and modified considerably by the steel making process, but can not be changed by any subsequent treatment short of remelting. "If methods could be devised to produce steel at reasonable costs without reaching the liquid condition, a multitude of present metallurgical difficulties would become nonexistent." Structural steel might (ideally) have Izod impact of 75 ft-lb. and Brinell hardness of 110. After 4 to 6% reduction by cold work exceptionally insensitive heats of this steel would have impact from 50 to 60 and hardness of 130 to 140. An average expectancy would be 20 to 50 and 135 to 155 respectively, whereas for an unusually sensitive heat the figures would be down to 4 ft-lb. and 145 to 170. Brittleness and hardness would be later intensified by aging and these heats of sensitive steels are the ones which break under shock at places where the cold straightening press has bent them, and which develop cracks at punched holes or sheared surfaces. Owing to an excessive amount of spontaneous work hardening, they are also hard on the fabricating tools. All these effects are intensified in cold rolled or drawn products. Mr. Graham pointed out that the entire program of steel making and fabrication can be standardized and yet the variables due to "sensitivity" will remain, for they date back to the melting processes, and in our present state of knowledge are uncontrollable.

CONCENTRATES

A STEADY development in the size and complexity of steel castings used for railway rolling stock has taken place since 1905, largely through the efforts of Commonwealth Steel Co. and General Steel Castings Corp. W. M. Sheehan describes these enormous pieces in a serial article in *The Steel Founder*, January to April. Probably the first **STEEL CASTING**, forming in one unit a substitute for a combination of plates, shapes, rivets, bolts, forgings and castings, was the equalized swing-motion trucks for passenger cars. These are now standard. Nearly all new cars for fast trains have cast end frames to prevent telescoping in an accident; the door and corner posts, top and bottom sills and floor sills and joists extending backward over the trucks are a single piece. Locomotive frames are not only one piece with all cross bracing, but cylinders are cast en bloc and an air reservoir forms the central backbone. The skin of low carbon steel castings resists corrosion of sea air and high sulphur coal smoke, as 20 years' service records prove, so similar one-piece tender bottoms are very popular. These have solid horizontal diaphragms, water tight, and thus form the tank bottom, providing 2000 gal. extra water capacity and lowering the center of gravity materially. Similar solid underframes have been made for tank cars; draft mechanism is contained in appropriate pockets. Pedestals are cast integral and are provided with case hardened steel liners, bushings and pins. Eventually we may have hopper cars, cast in one piece.

IRON is melted by Saginaw Malleable Iron Co., in a cupola (charge being steel, white-iron sprues and high-silicon silvery iron) desulphurized in a large mixing ladle and superheated in an arc furnace. Annealing in a continuous kiln requires 96 hr. and produces metal with 12 to 18% elongation. C. F. Joseph and A. L. Boegehold have described the sudden display of **ANNEALED CASTINGS** with speckled dull fracture and elongation of only 10 to 13% which required a double anneal. (Their paper was presented at Milan last fall and again before the American Foundrymen's Association



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The Steeloscope pictured above will assist you in determining the alloy elements in steel. And the Production Brinell Machine at the left, though hand operated (with consequent low cost), is faster in operation than most motor-operated machines.

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Rip Van Winkle won't be at BUFFALO

THE past year has been slow in the factors which the general public sees—active beyond parallel *behind the scenes* where technical research has driven ahead to a wealth of new discoveries and improvements.

The concern which sleeps on its feet until the pick-up in business becomes self-evident will find itself (like poor Rip Van Winkle after his famous snooze) expensively out of touch with progress.

In the Metal Industries there was never a time when, in sheer self-defense against the future, management needed to be more alert, more open-minded to new developments, or better informed as to those developments.

At Buffalo, from Oct. 3 to Oct. 7, more than one-hundred-and-twenty-five exhibitors will bring together for your inspection the fruits of this year of aggressive research and development. The leading experts of nine technical societies will deliver approximately one-hundred papers based on data secured from the past year's intensive study, material never before presented in any form.

To be prepared for the up-grade, you and your associates should be at Buffalo Oct. 3 to 7, 1932.

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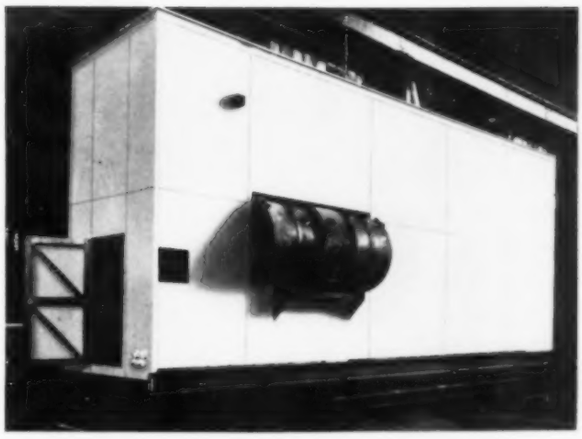
BUFFALO, N. Y., OCTOBER 3 TO 7, 1932 •

last month in Detroit.) When silvery pig from another source was used the trouble stopped, and now all shipments of iron are sampled in advance of acceptance, melted in small electric-furnace heats, and the castings annealed in regular routine. Pig iron making normal malleable has been secured from three blast furnaces; each has also furnished iron which makes speckled castings. The latter pig iron, polished and etched, shows considerable areas of phosphorus-rich metal, but normal high-phosphorus malleable is common. Addition of 0.03% titanium to the foundry ladle causes the trouble, but one silvery pig containing 0.12% Ti made normal malleable and another 0.12% Ti iron made speckled castings. When the last mentioned pig was made, the blast furnace was using 1% of a high phosphorus, high titanium ore; when this was eliminated the silvery iron was acceptable. The conclusion is that the trouble was due to an unknown quality in the silvery pig iron and therefore each shipment must be given a proof test.

AT the St. Louis meeting of the American Zinc Institute in April much consideration was given to the processes for recovering metal from complex ores. In 1920 these, including differential flotation, "waelz" process of separation by volatilization and the electrolytic process produced only one ton of metal to every 12 coming from pure, rich ores via the retort, whereas in 1931 the world ratio was 1 to 2. Owing to the ease with which **ZINC** may now be produced at regions far distant from a cheap fuel supply, this revolution in processes will probably continue even further. Zinc consumption for galvanizing and dry cells has meanwhile sharply decreased; die casting, the one large new use, is confined to America, and frequently replaces zinc-consuming brass. About 100,000 tons of zinc are made annually by the waelz process, which treats a mixture of raw ore and coal at a temperature below the sintering point in a long rotating cylinder, like a cement kiln. Little if any added heat is necessary. Zinc oxide may be sold as such, or reduced to metal in an electrolytic zinc plant.



General Electric X-Ray equipment specially designed for inspection of longitudinal and circumferential fusion welds and installed at Jersey City Plant of The M. W. Kellogg Co.

M.W. Kellogg Co. plant
G-E equipped for X-Ray inspection of fusion welds

THIS General Electric x-ray equipment, operating at 300,000 volts and recently installed at the Jersey City, N. J. plant of The M. W. Kellogg Co., for non-destructive examination of fusion welds in pressure vessels, is one of the largest and most powerful x-ray generators in industrial use at the present time. Through a unique system of mounting and controls it is easily adjusted laterally, longitudinally and vertically for the radiography of tubes of any length and from three to fifteen feet in diameter.

X-ray equipment is rapidly taking a prominent position in the production line as an inspection tool of great accuracy, with a wide range of usefulness. Our Industrial X-Ray Department is continually devising and installing specialized apparatus for the examination of welds, castings, rolled and drawn materials, hidden assemblies—in fact, for every manufacturing process where hidden defects present a problem. New and improved equipment for crystal analysis by means of diffraction patterns has also been made available to the metallurgist.

Let us keep you abreast of the latest developments in this field. Literature describing and illustrating the many industrial applications of the x-ray will be sent on request. Address Industrial Department.

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researches of Piwowarski on improving the quality of iron by proper overheating.

It would take too much space to give examples of the different types of iron castings that can be conveniently manufactured. One, chosen from among the more common, both for the tonnage and for the composition of the iron, may perhaps give at least an approximate idea of the working conditions.

The charge contained 4000 lb. of ordinary gray iron turnings (3.5% C) and 6000 lb. of sheet scrap (0.22% C). To this was added 400 lb. of petroleum coke.

When completely melted, four hours later, the carbon content of the metal was 2.95%, showing that little oxidation had occurred and two-thirds of the coke had been absorbed. After charging 300 lb. of 60% ferrosilicon, and 120 lb. of 47% ferromanganese, the temperature was raised to about 2900° F., and the metal tapped. Its composition was then: total carbon 2.98%, combined carbon 0.88%, silicon 1.50%, manganese 0.67%, sulphur 0.10% and phosphorus 0.21%.

This is the composition of a real pearlitic iron. In fact, the graphite was finely divided and uniform, showing in many places the characteristic of a typical eutectic. Little primary cementite was in evidence and there was no trace of ferrite. The pearlite had a very fine structure.

Its shearing stress was about 60,000 lb. per sq.in., tensile strength 44,000 lb. per sq.in. and the Brinell hardness 269. The bend test on a bar 8x10 mm. in cross section with 30-mm. span, gave breaking loads of about 920 kg. and deflections varying between 0.24 and 0.27 mm.

These results are especially interesting when it is remembered that very cheap raw materials were used, and that very strong overheating was obtained with a fuel consumption of 14% of the weight of iron tapped. Since the fuel was a pulverized coal containing 28% volatile, the total cost of melting was very low.

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. . . . provides a proportional and absolute standard of hardness by the plastic indentation method. There is nothing empirical about it. It will test difficult specimens such as sheets under .007" thick; gear teeth on the working face; finished coil springs, etc., without damage. It is semi-direct reading and very fast . . . . In research work into the constitution and properties of nitrided steel cases, after a trial of other Hardness Testing Machines, this machine was selected as the most suitable, as besides the hardness, it indicates the friability of the case, which is a measure of its wearing qualities.

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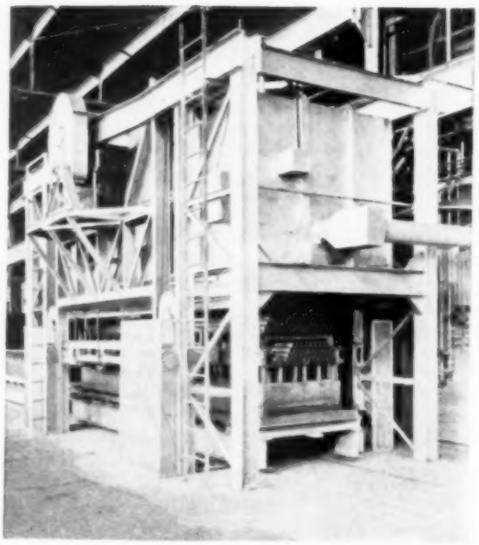
Controlled-atmosphere controlled-cooling annealing furnace



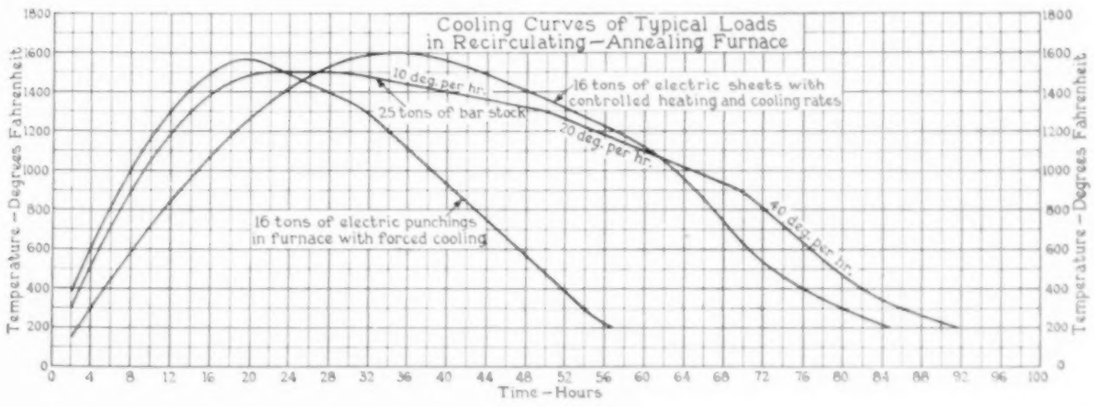
G-E elevator-type annealing furnace with controlled atmosphere and recirculating cooling system. Note charge of tubes.

WITH the G-E controlled-atmosphere, controlled-cooling-rate electric furnace, you can anneal at exactly the right temperature and cool at exactly the correct rate. High-carbon-steel and alloy-steel products can be annealed in a neutral atmosphere without the use of covers or containers and without oxidation or decarburization.

For controlled cooling, the atmosphere is recirculated through a surface air cooler. This permits cooling at high or low rates as desired — in fact, controlled cooling may be carried to almost room temperatures.

See the graph below; it speaks for itself.

Every manufacturer of bar stock, tubing, sheets, etc. is urged to investigate this important furnace. Be prepared to meet the increasingly rigid specifications of modern markets. It will pay you to take advantage of the equipment and engineering service that we offer. Consult your nearest G-E office, or the General Electric Company, Schenectady, N. Y.


Cooling Curves of Typical Loads
in Recirculating—Annealing Furnace
Temperature—Degrees Fahrenheit
Time—Hours
10 deg. per hr.
16 tons of electric sheets with controlled heating and cooling rates
25 tons of bar stock
20 deg. per hr.
40 deg. per hr.
16 tons of electric punchings in furnace with forced cooling

570-181

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Welded Construction—Bethlehem Steel Co. describes advantages of welded construction in building machinery parts from rolled steel parts and shapes. Results are said to be sturdier construction. Bulletin J-76.

Hardness Testing—Pamphlets are available from Shore Instrument Co. describing the Monotron and Scleroscope hardness testing machines. Bulletin J-33.

Ferro-Carbon Titanium—An illustrated 111-page catalog technically describing this alloy and its use in steel for forgings, steel castings, rail steel, sheets, plates, etc., is offered by Titanium Alloy Mfg. Co. Bulletin J-90.

Convector Furnaces—W. S. Rockwell Co. has prepared a pamphlet describing its line of electric convector furnaces which operate at temperatures up to 800° F. for drawing and bluing. Bulletin RO-332.

Refractory Materials—Norton Co. offers a semi-technical booklet giving valuable information on the manufacture, use and application of fused alumina (Alundum), silicon carbide (Crystolon) and fused magnesia refractories products. Bulletin J-88.

Welding Electrodes and Accessories—General Electric Co. has a new bulletin which describes its line of welding supplies and accessories. Many illustrations. Bulletin J-60.

Fatigue Testing Machine—Thompson Grinder Co. Interesting data on fatigue testing and description of the rotating beam type of fatigue testing machine are given in Bulletin D-23.

Electric Heat Treating Furnaces—Ajax Electric Co., Inc. Photographic description of new electric furnaces for annealing wrought products, such as sheet, wire, tubing, rod, etc. Bulletin D-83.

Metal Progress, 7016 Euclid Ave., Cleveland.

Please have sent to me the following literature as described under "Industrial Publications" in the June issue of METAL PROGRESS. (Please order by number.)

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Hy-Ten Alloy Steels—Wheelock, Lovejoy & Co., Inc. "Pertinent Points" folders covering physical properties, heat treatment and applications of all grades of Hy-Ten Special Steels. Bulletin D-22.

"Carbonol Process for Carburizing Steels" is the title of the new 12-page bulletin published by the Hevi-Duty Electric Co. The bulletin describes the results and advantages of the Carbonol process of carburizing. Bulletin N-44.

Nitriding Steel—Properties of a new chromium-vanadium nitriding steel developed by Union Carbide & Carbon Research Laboratories are listed in a new publication of Electro Metallurgical Sales Co. MM-16.

Globar Elements and Accessories—Globar Corp. A new leaflet containing a list of standard industrial type Globar electric heating elements and a coordinated list of terminal mountings and accessories. Bulletin N-25.

Chromel Couples—Hoskins Manufacturing Co. Bulletin contains technical data on pyrometer couples. Bulletin M-24.

Micro-Metallograph—E. Leitz, Inc. A precision instrument for making accurate photomicrographs without distortion and with absolute flatness of field is described. Bulletin M-47.

Recuperators—Carborundum Co. The complete story of Carborundum Co. recuperators for industrial furnaces, describing the type and covering operating conditions. Bulletin F-57.

Heat and Corrosion Resistant Alloys—General Alloys Co. A new bulletin is available on chrome-nickel and straight chrome heat and corrosion resisting alloys. Bulletin D-17.

Welded Pipe—Republic Steel Corp. has prepared a booklet on its electric weld line pipe and casing. Manufacturing processes and performance data are presented. Bulletin AA-8.

Furnace Parts—Driver-Harris Co. has issued a bulletin featuring furnace parts made of their alloys. This bulletin gives data and advantages of Nichrome and Chromax heat resisting alloys in the form of furnace parts. Bulletin N-19.

High Frequency Induction Furnaces—Ajax Electrothermic Corp. New bulletin gives detailed information regarding Ajax-Northrup high frequency induction furnaces operated from static converters, for laboratory use or for small-scale production. Bulletin JA-41.

Circulating Oil Tempering Baths—A folder recently issued by American Electric Furnace Co. describes several models of their electrically heated oil tempering baths of the circulating type. Bulletin M-2.

Thermocouple Heads—Leeds & Northrup Co. offer a folder descriptive of their new Universal thermocouple heads. Photographs show simplicity of installation. Bulletin M-46.

Peroxygen Compounds—A 24-page booklet issued by Roessler & Hasslacher Chemical Co. presents briefly the characteristics and uses of a number of peroxygen compounds. Bulletin M-29.

Wear and Lubricant Tester—Timken Roller Bearing Co. has prepared a description of a new machine for testing load carrying capacity of lubricants, measuring friction and wear of materials. Bulletin M-71.

Photographic Dilatometer—R. Y. Ferner Co. Catalogue illustrates the Chevenard equipment for studying the effects of heat upon materials. Bulletin M-91.

Machine Heat Treating—American Gas Furnace Co. A 16-page illustrated booklet giving information on the various types of conveyor heating machines available for heat treating on a production basis. Bulletin D-11.

Thermit Welding—Metal & Thermit Corp. A 52-page booklet on the thermit welding process and its applications. Photographs and descriptions typical of its varied uses are given, showing how Thermit is fundamentally adapted when large sections are involved. Bulletin D-64.

Modern Industrial Furnaces—Surface Combustion Corp. Booklet covering the research, development and engineering activities of the Surface Combustion Corp., and their application and the advantages obtained by S-C furnace users as a result of these factors. Bulletin N-51.

Gears Made of Armor Plate—The International Nickel Co. Reprint of article by Robert E. Bultman originally published in May, 1931, issue of METAL PROGRESS. Booklet deals with the use of 5 per cent nickel and nickel-chrome steels for motor truck gears and pinions. Bulletin D-45.

Scale Prevention—Dearborn Chemical Co. Booklet describing latest scientific methods of treating water for prevention of scale, corrosion and foaming in steam boilers, dealing with related problems in connection with scale and corrosion in other power plant equipment. Bulletin D-36.

Industrial Application of the X-Ray—General Electric X-Ray Corp. Booklet gives many examples of the use of the X-Ray in the industrial field. Profusely illustrated with radiographs of castings, welds, assemblies, etc. Bulletin D-6.

Furnaces for the Steel Industry—The Electric Furnace Co. have issued a four-page folder illustrating and listing several electric and fuel fired furnaces of various types they have installed in steel plants. Bulletin D-30.

Ingot Molds—Gathmann Engineering Co. The subject of ingot molding is covered in a new book on this subject. Numerous illustrations of the effect of various methods of finishing and casting on the reliability of steel products are given. Bulletin D-13.

Quenching—A new 80-page book, "Houghton on Quenching," containing over 30 charts and photomicrographs, has just been published by E. F. Houghton and Co. MM-38.

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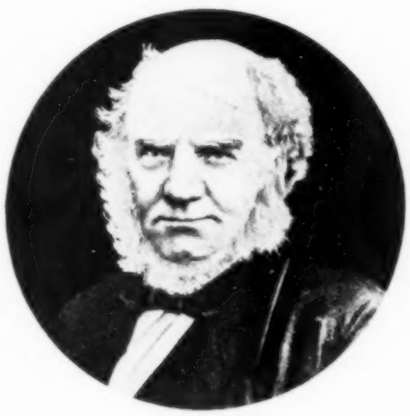

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(Continued from page 34) be of prime importance in Permalloy, and as no satisfactory explanation has yet been offered to account for the improvement due to the special heat treatment, I wish to suggest that quenching prevents segregation and consequently produces a more homogeneous structure than is possible by slow cooling.

Finally, what about nickel, Ni_4 of Fig. 7? As ordinarily made, its magnetic properties are poor in every respect, and so far there is no indication that improvements similar to those noted above for Fe_3, Fe_2Ni_3, and $FeNi_3$ are obtainable. It should be pointed out, however, that comparatively little work has been done on this metal, and it is quite probable, if subjected to the same intense investigation as the others, that it will yield surprises just as great.

As a closing picture I have combined in Fig. 9 the magnetization curves for the above five materials and for comparison have added the curve for the purest commercial iron available at present. (See page 34.)

Contributions by Others

The history of Hipernik would be incomplete without referring to the valuable contributions made by A. A. Frey to its steady growth from infancy to the present day. Numerous difficulties have had to be overcome in order to enable the mills and the shops to produce Hipernik on a commercial scale, and Mr. Frey has always been in the front rank in the campaigns for solving these practical problems. A few years ago, J. B. Seastone also joined the Hipernik family and is now in charge of the development plant in East Pittsburgh. Under his able management, the principles underlying the heat treatment of Hipernik have been carried into successful commercial practice. Mention should also be made of the valuable cooperation of the staffs of the International Nickel Co. and of the American Rolling Mill Co. in making it possible to produce Hipernik base in commercial furnaces and in tonnage lots.